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Subj: GREATLAND LASER RESCUE FLARE LASER SAFETY EVALUATION

Encl: (1) Laser Hazard Evaluation Report

1. Laser safety measurements of the Greatland Laser Rescue Flare were performed on 16 June 2006 at NSWC Dahlgren, Virginia. The purpose of these measurements was to perform a laser hazard evaluation. The results of the laser safety measurements and calculations are given in enclosure (1). The compliance analysis in accordance with OPNAVINST 5100.27A/ MCO 5104.1B is included with the exceptions mentioned in the Report.

2. Any questions concerning this laser safety evaluation may be directed to Sheldon Zimmerman, DSN 249-1060/commercial (540) 653-1060.

MICHAEL A TILL
By direction

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GREATLAND LASER RESCUE FLARE LASER HAZARD ANALYSIS

SHELDON ZIMMERMAN, CODE G73
LEAD NAVY TECHNICAL LABORATORY
FOR NAVY AND MARINE CORPS LASER SAFETY

JUNE 2006

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1 INTRODUCTION

The Naval Sea Systems Command, as the Department of the Navy (DoN) Technical Lead Agent for laser safety, has established the Naval Surface Warfare Center Dahlgren Division Code G-73 as the Lead Navy Technical Laboratory (LNTL) for laser safety. Part of this responsibility includes the laser hazard evaluation of systems used on DoN installations or by DoN personnel. Furthermore, measures are recommended to eliminate exposure of personnel to hazardous optical radiation from these devices.

A laser hazard evaluation includes measurements of the laser output parameters to determine the hazard class of the laser, minimum required eye protection, and the distance from the laser where optical radiation levels fall below the current protection standard.[1] It is the current policy in the laser safety community to determine the output parameters using data collected in lab and field measurements.

The LNTL was requested by the Marine Corps Warfighting Laboratory to evaluate the Greatland Laser Rescue Flare. The results of the evaluation are presented in this report.

2 LASER SAFETY THEORY

2.1 Purpose

Laser hazard evaluations are conducted to provide information to help minimize the potential for injury to personnel from lasers and laser systems and to verify laser beam parameters of new or modified laser devices. As part of this evaluation, the associated hazard distances for the eyes and skin are determined as are the optical requirements for laser protective eyewear. Also, an analysis is conducted to determine whether the laser system is in compliance with the current DoN laser safety standard, OPNAV 5100.27A / MCO 5104.1B.

2.2 Accessible Emission Limit (AEL) and Maximum Permissible Exposure (MPE)

To determine the hazard level for an exposure scenario, the energy that could pass through a limiting aperture, $\mathbf{D_f}$, (i.e. the pupil of the eye) is compared to the class 1 **AEL**. This **AEL** is based on the **MPE** values currently established by the American National Standard Institute. The Navy has accepted the **MPE** values from the ANSI standard. The **MPE** is a function of laser wavelength, pulse duration, exposure duration, pulse repetition frequency, and the nature of the exposure (intrabeam, diffuse reflection, or skin). The **AEL** is calculated by multiplying the appropriate **MPE** by the area of the limiting aperture as shown in equation 1.

$$\boldsymbol{AEL} = \frac{\boldsymbol{MPE} \cdot \pi \cdot \boldsymbol{D_f}^2}{4} \qquad (1)$$

If the potential exposure is less than the class 1 **AEL**, the exposure is considered non-hazardous.

2.3 ANSI Laser Hazard Classification

The ANSI laser hazard classifications are used to signify the level of hazard inherent in a laser system and the extent of safety controls required. These range from class 1 lasers (which are safe for direct beam viewing under most conditions) to class 4 lasers (which require the most

[1] American National Standards Institute Inc., *American National Standard for the Safe Use of Lasers*, ANSI Z136.1-2000.

strict controls). If applicable, ANSI classification is based on the worst case of unaided viewing and viewing with the use of 7x50 binoculars.

2.4 Laser Beam Propagation

2.4.1 Beam Diameter (D_L)

As a laser beam with a Gaussian spatial profile propagates through a medium such as air or water, it produces a profile as shown in Figure 2-1. The beam diameter, $\mathbf{D_L}$, is a function of range, **r**, from the exit port or beam waist, initial beam diameter, **a**, and beam divergence, **ϕ**, and can be calculated using equation 2.

$$D_L = \sqrt{a^2 + r^2\phi^2} \qquad (2)$$

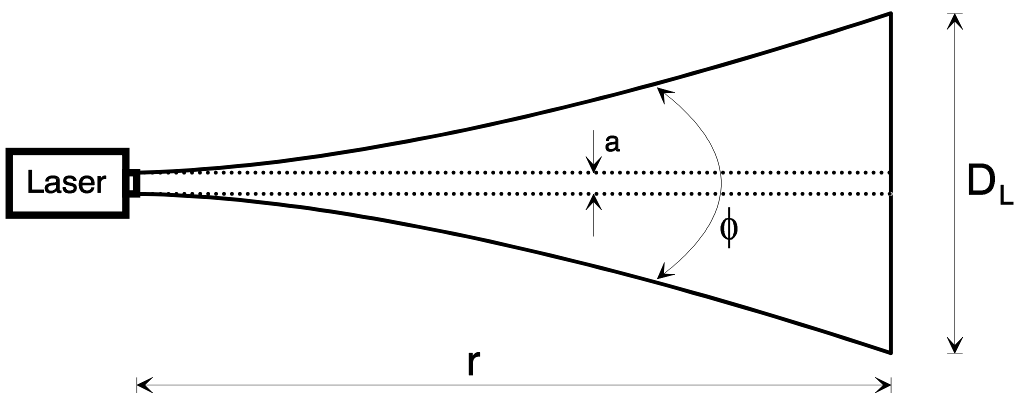

Figure 2-1. Laser Beam Geometry

2.4.2 Atmospheric Attenuation Coefficient (μ)

As laser radiation propagates through the atmosphere or any material medium, its intensity is attenuated by absorption and scattering. After propagating a distance, **r**, through the atmosphere, where $\mathbf{Q_o}$ is the total emitted pulse energy and **μ** is the atmospheric attenuation coefficient, pulse energy, **Q**, can be found using equation 3.

$$Q = Q_0 e^{-\mu \cdot r} \qquad (3)$$

This equation shows that the intensity falls off exponentially as a function of the distance from the laser source. The attenuation coefficient is dependent on the wavelength of the laser and the medium through which it is passing. Because of the combination of absorption and scattering effects, the attenuation coefficient is a complex function of wavelength having a large value at some wavelengths and a small value at others. Figure 2-2 shows this exponential loss as a function of range for several values of **μ**. It is standard practice in the laser safety community to assume the atmospheric attenuation coefficient assuming an exceptionally clear day.

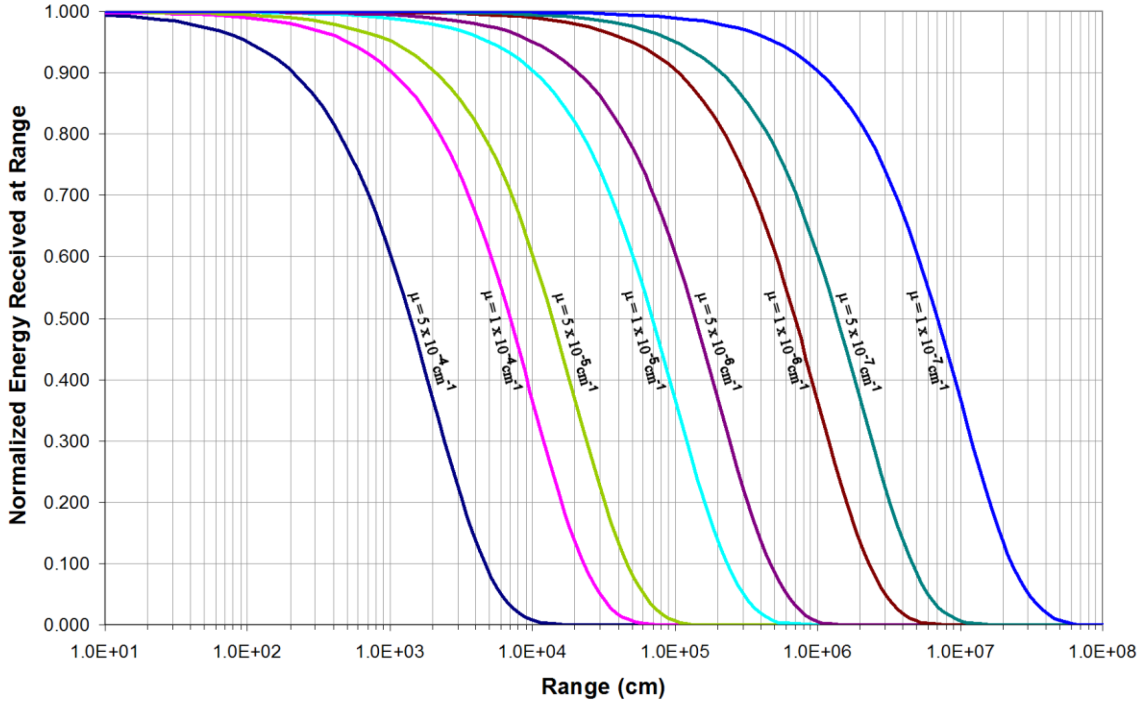

Figure 2-2. Atmospheric Attenuation

2.4.3 Scintillation

Scintillation is another important effect of the atmosphere. Scintillation is caused by random variations in the index of refraction of the atmosphere. These index variations are caused by localized temperature and pressure fluctuations. This can result in focusing effects which create hot spots in the beam pattern, most pronounced at long ranges. The effect of scintillation creates the illusion of twinkling light at the bottom of a swimming pool on a sunny day and mirages in the desert.

2.4.4 Reflections

When a laser beam is incident on a surface, the reflected optical radiation has a specular (mirror like) and a diffuse (scattered) component, each varying in magnitude as a function of the material the laser is striking and the wavelength and polarization of the laser beam. Objects like glass produce predominantly specular reflections while objects such as walls and paper produce predominantly diffuse reflections. A reflection from a specular reflector will be hazardous for a longer distance than one from a diffuse reflector due to the continued collimation of the reflected beam. The divergence (increase in beam size as a function of range) of a specular reflection depends on the flatness of the reflector. Figure 2-3 illustrates the effect of a diffuse reflector and a specular reflector on an incident laser beam.

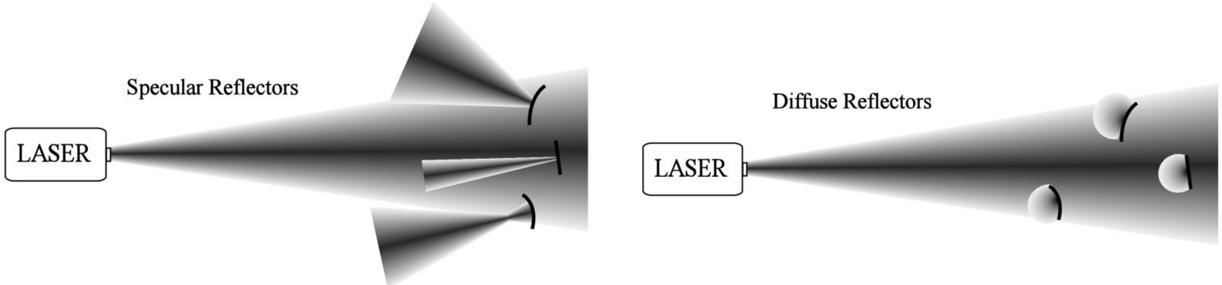

Figure 2-3. Effects of Specular Reflector and Diffuse Reflector on Incident Laser Beam

When optical energy, **Q**, is incident on a surface, the amount of energy reflected, $\mathbf{Q_R}$, transmitted, $\mathbf{Q_T}$, and absorbed, $\mathbf{Q_A}$, depends upon the type of material present. Equation 4 shows that the sum of these three components is equal to the total incident energy.

$$\boldsymbol{Q = Q_R + Q_T + Q_A} \qquad (4)$$

The amount of energy reflected from the interface depends on the angle of incidence and the polarization of the incident beam. Given the parallel polarized component of the beam, $\mathbf{P}_{\parallel}$, and the perpendicular polarized component of the beam, $\mathbf{P}_{\perp}$, the percentage of the total incident energy that will be reflected, **R**, can be determined using equation 6.

$$R = P_{\parallel}\left[\frac{\tan^2(\theta_i - \theta_t)}{\tan^2(\theta_i + \theta_t)}\right] + P_{\perp}\left[\frac{\sin^2(\theta_i - \theta_t)}{\sin^2(\theta_i + \theta_t)}\right] \qquad (6)$$

In equation 6, the sum of $\mathbf{P}_{\parallel}$ and $\mathbf{P}_{\perp}$ must equal 1.0. For a laser with random polarization, both terms are assumed to be 0.5. The effect of this could produce a hazard zone as shown in Figure 2-4. This example assumes a randomly oriented circular piece of glass with a one-half inch diameter with reflection off both the front and rear surfaces.

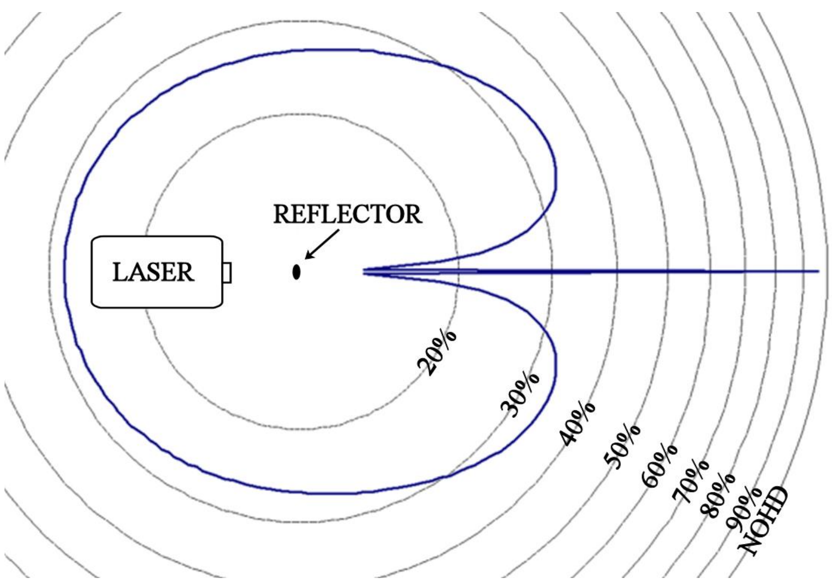

Figure 2-4. Hazard Zone Created by Reflected Laser Energy from a Randomly Oriented Circular Piece of Glass

2.5 Hazard Distance

The eye is the most sensitive part of the body to damage from most lasers currently in use on DoN ranges (visible and near infrared lasers). Figure 2-5 shows how the light from a conventional light source is focused by the eye to form an extended image on the retina; whereas laser radiation is typically focused onto a very small spot on the retina. When viewing a source such as a laser or distant star, the retinal irradiance is greatly amplified over the corneal irradiance. It is this focusing effect that makes the eye more sensitive to laser radiation than any other part of the body.

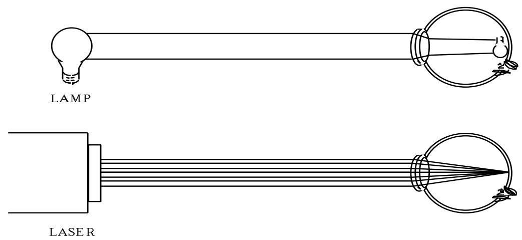

Figure 2-5. Focusing of Laser Beam and Conventional Light Source by the Eye

Equation 7 describes the relationship between effective energy (energy through an aperture), $\mathbf{Q_f}$, to total energy, $\mathbf{Q_0}$, given the beam diameter, $\mathbf{D_L}$, and the aperture diameter, $\mathbf{D_f}$, while neglecting atmospheric losses and assuming a laser beam with a Gaussian spatial profile.

$$\frac{Q_f}{Q_o} = \tau \cdot \left[1 - e^{-\left(\frac{D_f^{\,2} \cdot G_f}{D_L^{\,2}} \right)} \right] \tag{7}$$

In equation 7, $\boldsymbol{\tau}$ is the transmission of energy through viewing aids and $\mathbf{G_f}$ is the effective optical gain (gain as it relates to safety) of those viewing aids. When not considering viewing aids, both terms are set equal to 1. Equation 8 is derived from equation 7 by substituting equations 2 and 3 into it. This shows the relationship between total and effective energy as a function of range and includes atmospheric loss.

$$\frac{Q_f}{Q_o} = \tau \cdot e^{-\mu \cdot r} \left[1 - e^{-\left(\frac{D_f^{\,2} \cdot G_f}{a^2 + r^2 \cdot \phi^2} \right)} \right] \tag{8}$$

A hazard distance can be defined as the range at which the power or energy entering the limiting aperture exceeds the class 1 **AEL** for the laser wavelength and exposure duration as defined by the appropriate limiting aperture.

If **AEL** is substituted for $\mathbf{Q_f}$ in equation 8, the range, **r**, becomes the hazard distance, **HD**. Making these substitutions and solving for **HD** creates equation 9.

$$HD = \frac{1}{\phi} \sqrt{ \frac{-D_f^{\,2} \cdot G_f}{\ln\left(1 - \frac{AEL}{Q_o \cdot e^{-\mu \cdot HD}} \right)} - a^2 } \tag{9}$$

At distances greater than the hazard distance, the observer will not be exposed to energy levels greater than the class 1 **AEL** and is considered to be safe. At distances less than the **HD**, the observer must wear personnel protective equipment (such as laser safety goggles) to reduce the potential of exposure to energy levels above the class 1 **AEL**.

The hazard distance for the eye is referred to as the nominal ocular hazard distance, **NOHD**. The hazard distance for the skin is referred to as the nominal skin hazard distance, **NSHD**.

2.6 Eyewear Optical Density Requirements

To determine the necessary optical density, **OD**, of eyewear to protect personnel from incident laser radiation, the ratio of the effective energy, $\mathbf{Q_f}$, to the class 1 **AEL** is used as shown in equation 10.

$$OD = \log_{10}\left(\frac{Q_f}{AEL}\right) \tag{10}$$

Since some lasers or laser systems may produce energy or power well above one million times the class 1 **AEL**, the use of logarithms is the preferred method when describing personnel protection requirements. To fully specify the eye protection requirements for a particular laser system, unaided and aided **OD** values are needed.

It should be noted that the maximum **OD** requirement for a laser system is calculated by assuming that all laser energy is collected within the limiting aperture as is shown by equation 11.

$$OD_{\max} = \log_{10}\left(\frac{Q_0}{AEL}\right) \tag{11}$$

2.7 Laser Range Buffer Zones

On laser ranges, a buffer zone must be established and utilized for each laser system. A buffer zone is a conical volume centered on the laser's line-of-sight with its apex at the laser aperture. Within the buffer zone, the beam will be contained with a very high degree of certainty. The laser system's buffer zone depends on the aiming accuracy and boresight retention of the laser system. Typically, the laser system's buffer zone is equal to five times the system's aiming accuracy. Typical buffer zones for some military lasers are given in Table 2-1.

Table 2-1. Laser Output Parameters

Situation	Buffer Angle
Laser in a stationary tank	2 mrad
Laser on tripod, moving tank, or aircraft with stabilizing optics	5 mrad
Hand-held laser in an aircraft, or in a moving vehicle without stabilizing optics	10 mrad (minimum)

3 SYSTEM CONFIGURATION

The Rescue Flare is a hand-held laser device that provides a bright green swath of light that can be swept across aircraft/searchers to aid in rescue location. The system is configured much like a flashlight and is shown in Figure 3-1. It has a screw-on cap that activates the laser when it is fully tightened or provides a push-button activation when unscrewed ¼-turn. The laser source is a solid state diode. The safety parameters of the system are unclassified and are included in this report.

Figure 3-1. Rescue Flare Photos (holes in table are 2.54 cm on center)

4 HAZARD EVALUATION

4.1 Evaluation Information

This evaluation was performed at NSWC Dahlgren, Virginia. Sheldon Zimmerman was the NSWCDD evaluator for this system.

4.2 Equipment Used

Table 4-1 describes the equipment used during testing for this hazard evaluation.

Table 4-1. Equipment Used

S/N	Description	Calibration Due Date
116490	Ophir LaserStar	8/12/06
50289	Ophir PD-300 Detector	8/12/06
Miscellaneous Equipment: Calipers		

4.3 Evaluation Method

The system was evaluated using methods discussed in this report. The following methods or tests were done as part of this evaluation.

4.3.1 Spatial Energy Profile

The beam spatial energy profile was estimated based on visual inspection of the beam at various ranges from the laser. It is a near-elliptical beam with a Gaussian profile as shown in Figures 4-1 and 4-2.

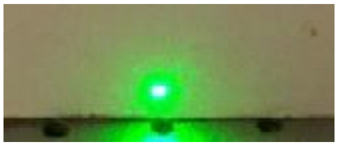

Figure 4-1. Rescue Flare Beam at 14 cm (holes are 2.54 cm apart)

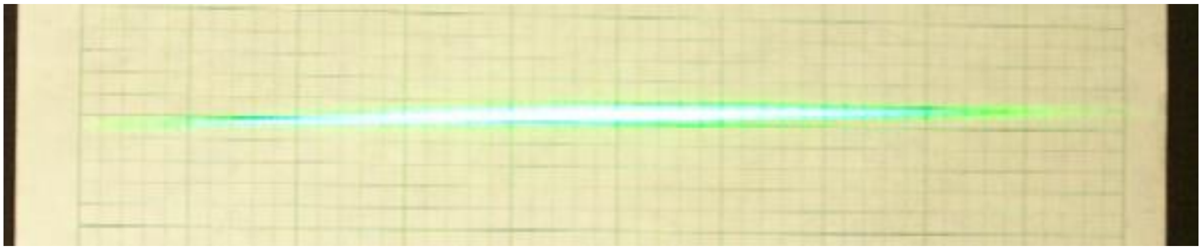

Figure 4-2. Rescue Flare Beam at 6.1 m

4.3.2 Total Output Power

The total output power of the unit was measured directly using the Ophir detector and meter. The system has an output power of up to 5.0 mW.

4.3.3 Beam Size

The beam size was determined visually. It is shown in Figures 4-1 and 4-2.

4.3.4 Beam Divergence

The beam divergence was measured using the two-point method. The beam size was measured at two positions and the divergence was calculated from those results. The measurements yielded 31 x 1.1 mrad. The value used in calculations was 31 x 1.1 mrad.

4.3.5 Wavelength

The wavelength was measured with a monochromator and was found to be 532 nm with a 10 nm tolerance. The specification is 532 nm. Leakage of 1064 nm radiation was examined before it was found that the laser medium is a laser diode. There was no detectable 1064 nm radiation.

4.4 Evaluation Discussion

Hazards were calculated using methods and equations discussed in this report. The calculations for the laser designator mode are based on **MPE** values of 2.5 mW/cm^2 for the eye and 0.2 W/cm^2 for the skin. An overall exposure time of 0.25 seconds was assumed. The worst case of measured or specified values were used in this hazard evaluation.

4.5 Results

No hazardous secondary beams or other unwanted hazardous emissions were found to be associated with the system. The unclassified system parameters used in performing the hazard analysis for these lasers is given in Table 4-2. The results of the laser safety calculations are given in Table 4-3.

Table 4-2. Laser Output Parameters

Wavelength	532 nm
Beam Size	1.1 mm circle that grows to an ellipse
Beam Divergence	31 x 1.1 mrad
Total Output Power	5 mW

.

Table 4-3. Laser Safety Parameters

ANSI Classification	3a Danger
IEC Classification	3R
NOHD (unaided)	2.64 m
NOHD (5-cm aided)	17.8 m
NOHD (8-cm aided)	28.5 m
NOHD (12-cm aided)	49.9 m
NSHD	0 m
OD (unaided)	0.8
OD (aided)	0.8
OD (max)	0.8

4.6 Design Requirements Analysis

The Rescue Flare was checked for compliance with the design requirements listed in OPNAV 5100.27A/MCO5104.1B, and the discrepancies found are listed below:

- The manufacturer label is incomplete – address incomplete (Item 1a)
- The laser is not military exempt or labeled as such – IEC labeled (Item 2)
- The laser is not designed to (necessarily) preclude unintentional output – when the battery cap is screwed on all the way, the laser is activated (Item 4)

Device labels are shown in Figure 4-3.

Figure 4-3. Device labels

5 CONCLUSIONS AND RECOMMENDATIONS

The Rescue Flare is an ANSI Class 3a-Danger and IEC class 3R laser system. The system should to be brought into compliance with the OPNAVINST5100.27A/MCO5104.1B and must be reviewed by the Navy Laser Safety Review Board (LSRB) prior to use. The manufacturer, city, and state are listed on the label, but the street address is not listed. It is the opinion of the evaluator that the label is sufficient in this regard. The system does not need to be made military exempt. The laser is designed such that, when the battery is installed and the battery cap is fully tightened, the laser is activated. Given the intended use of the system as a rescue flare, this activation method is acceptable. As an example, one possible use would be treading water with the laser in one’s mouth signaling for rescue; a momentary switch would create problems in this application. Additionally, the evaluator spoke directly with the FDA CDRH compliance office on this issue, and the compliance officer said that, given the intended use of the system, the FDA would not object to this activation method.

Care should be taken when using this device for its intended purpose. Direct illumination of specular reflectors and personnel close to the laser output should be avoided.

LASER SAFETY DESIGN REQUIREMENT CHECKLIST

This checklist is intended to help the designer, procuring activity, or personnel responsible for laser safety stay within the laser safety design requirements for military lasers and associated support equipment. There may be requirements where the wording may not precisely apply to the particular situation; therefore, some individual interpretation of the requirements is necessary. Because each individual's interpretation of the requirements may differ, room has been made available to expand upon the answer to each requirement. This checklist should not be used by itself, but in conjunction with other references; e.g., MIL-STD-882,[2] ANSI Z136.1,[3] and SPAWAR-EE000-BA-GYD-010.[4]

EQUIPMENT DESCRIPTION

Equipment Name: Greatland Laser Rescue Flare ______________________________

Model Number: Green Rescue Laser Flare __________________________________

Serial Number: GLF532 H001023 _______________________________________

Manufacturer: Greatland Laser ____

Address: Anchorage Alaska _______________________________________

____

____

Responsible Authority: Kate Patton-Hall____

Address: ____

____

____

Point of Contact: Kate Patton-Hall____

Address: ____

____

____

Phone: ____

[2]MIL-STD-882C, *Military Standard System Safety Program Requirements*, 1993.
[3]ANSI Z136.1, *American National Standard for the Safe Use of Lasers*, American National Standard Institute Inc.
[4]SPAWAR-EE000-BA-GYD-010, *System Safety Checklist for Electrical/Electronic Equipment,* Space and Naval Warfare Systems Command.

Inspector: Sheldon Zimmerman ________________________

Date: 6-16-06____________________________________

SECTION 1 LASER DESIGN REQUIREMENT CHECKLIST

Item	Requirement	Yes/No	Comment
1	Is laser product provided with a tag or label permanently affixed to the device housing?	Y	
1a	Does such a tag or label contain the full name and address of the manufacturer, the laser model, and the place, month, and year of manufacture?	N	Address incomplete
1b	Is label or tag information not expressed in code?	Y	
2	In lieu of the certification label required by 21 CFR 1010.2; if laser is product exempted under 76EL-01 DOD, is a tag or label permanently affixed to the device housing so that it is readily accessible to view?	N	IEC labeled
2a	Does such a tag or label contain the following statement? **CAUTION** **This electronic product has been exempted from FDA radiation safety performance standards prescribed in Title 21, Code of Federal Regulations, Chapter I, Subchapter J, pursuant to Exemption No. 76EL-01 DOD issued on 26 July 1976. This product should not be used without adequate protective devices or procedures.**	N	
3	Are laser products operational and adjustment controls located so that human exposure to laser radiation in excess of the appropriate MPE is unnecessary for the operation or adjustment of such controls?	Y	
4	Is laser product designed to preclude unintentional laser output (e.g., spontaneous firing)?	N	When you put the battery cap on, the laser comes on
5	Are lasers and associated optics designed so that external secondary beams are not generated unless necessary for the performance of the intended function(s)?	Y	
6	Are focused beams, hot spots, and collateral radiation minimized?	Y	
7	Do lasers employing frequency shifting or harmonic multipliers reduce unnecessary emissions below MPE?	Y	
8	Is the laser system designed to preclude unintentional self-oscillation, mode-locking, double-pulsing, or unwanted modes, when practicable?	Y	

Item	Requirement	Yes/No	Comment
9	If unwanted modes cannot be eliminated, is laser classified as per the worst possible accessible emission level?	N/A	
10	Are interlocked protective housings provided to protect personnel from high-voltage sources and unnecessary laser and collateral radiation in excess of the AELs?	N/A	
10a	Is aural or visual indication of interlock defeat provided?	N/A	
10b	Do interlocks return to their normal operation when access cover or door is returned?	N/A	
11	When laser radiation exceeding ANSI AEL for Class 1 is accessible, are visual indicators readily visible while wearing suitable laser protective eyewear?	N/A	Output beam is the only indicator and is not visible with eyewear
12	Do viewing ports and display screens, which allow the operator to view laser radiation, attenuate the radiation to limit personnel exposure to below the appropriate MPE?	N/A	
13	Do laser product pointing or viewing optics having a magnifying power exceeding 1.0 include a built-in laser safety filter within the optical train that protects the operator from reflections from specular surfaces or exposures from force-on-force training?	N/A	
13a	Is adequate visibility maintained when using laser safety filters?	N/A	
13b	Are laser safety filters permanently attached or designed so that the optical train cannot be assembled without the filter?	N/A	
13c	Is filter on viewing sight marked to indicate OD & wavelength?	N/A	
14	Is there a label marking the output aperture?	Y	
15	**Items 15-22 are Class 1, 2, and 3a laser requirements** Do laser warning labels for exempted lasers provide clear instructions to the operators, maintainers, and potential bystanders to preclude laser injury?	Y	
16	Do lasers classified as ANSI Class 1, Class 2, or Class 3a meet the design (performance) requirements of 21 CFR Class I, Class II, or Class IIIa, respectively, except where such requirements restrict operational capability or security?	Y	When you put the battery cap on, the laser comes on, but intended use permits it

Item	Requirement	Yes/No	Comment
17	Do lasers classified as ANSI Class 1, Class 2, or Class 3a meet the designation and warning requirements of 21 CFR Class I, Class II, or Class IIIa, respectively, with the exception that the ANSI classification will be displayed in the lower right corner rather than the FDA class?	Y	
18	Are labels permanently affixed or inscribed on such products as to be legible and readily accessible to view when the product is fully assembled for use?	Y	
19	Are warning labels affixed to the laser system housing near the beam exit port and/or fire button when possible in such a manner that viewing the label does not require personnel exposure to laser radiation?	Y	
20	Are Class 2 and Class 3a lasers, as defined by ANSI, provided with a label similar to the examples illustrated in Figure 1?	Y	IEC Labeled
20a	Is numerical output information [e.g., wavelength(s) and maximum power output (when unclassified)] located along the lower edge in a smaller font?	Y	
20b	Does the word **INVISIBLE** or **VISIBLE**, as appropriate, precede the word **RADIATION**?	N/A	IEC Labeled
20c	When labels may compromise camouflage, are muted colors appropriate to the camouflage paint scheme used?	N/A	IEC Labeled
20d	Is information classified in the interest of national security omitted from all labels?	N/A	IEC Labeled
21	When a laser has a defeatable interlock that, when defeated, allows access to Class 3b or Class 4 emission levels, is an additional label that states the following installed on or near the access panel? **DANGER** **Laser Radiation When Open and Interlock Defeated, Avoid Eye or Skin Exposure to Direct or Scattered Radiation**.	N/A	
22	If non-exempted lasers incorporate military labeling, has alternate labeling been requested by the manufacturer and approved as a variance by the FDA in accordance with 21 CFR 1040 (g) (10)?	N/A	
23	**Items 23-43 are Class 3b and Class 4 laser design requirements** Are Class 3b and Class 4 lasers, as defined by ANSI, provided with a label similar to the examples illustrated in Figure 2?	N/A	

Item	Requirement	Yes/No	Comment
23a	Are such labels permanently affixed or inscribed on such products to be legible and readily accessible to view when the product is fully assembled for use?	N/A	
23b	Is the label affixed to the laser system housing near the fire button and exit port when the port is remote from the operator in such a manner that viewing the label does not require personnel exposure to laser radiation?	N/A	
23c	Does the label use the word **DANGER** and include the type of laser and the word **VISIBLE** or **INVISIBLE** preceding the word **RADIATION**?	N/A	
23d	Does the label contain an appropriate instructional safety statement or control message for the operator or bystander as applicable? For Class 3b and Class 4 ground target designators: **DO NOT AIM AT PERSONNEL OR FLAT GLASS SURFACES** For Class 4 lasers that present a diffuse reflection hazard: **DO NOT AIM AT PERSONNEL OR FLAT GLASS SURFACES OR TARGETS WITHIN ___ METERS** Bystander warning for wavelengths 400 to 1400 nm; Class 3b and Class 4 lasers: **DO NOT LOOK INTO PORTHOLE** Bystander warning for wavelengths 1400 nm to 1 mm and 180 to 400 nm; Class 3b and Class 4 lasers: **DO NOT EXPOSE EYE OR SKIN TO DIRECT OR SPECULARLY REFLECTED BEAMS**	N/A	
23e	Do **DANGER** labels have **DANGER** printed upon a white background with a bright red oval around the word **DANGER** and contain a red starburst and black lettering?	N/A	
23f	When camouflage maybe compromised by such warning labels, are appropriate muted colors (i.e., olive drab) used?	N/A	
23g	If the information is unclassified, are the ANSI laser hazard classification, wavelength(s), and maximum radiant power or energy added along the lower edge of the label?	N/A	

Item	Requirement	Yes/No	Comment
24	Are measures taken to prevent single operator or material error causing unintentional laser output that exceeds ANSI AEL for Class 1?	N/A	
25	Are at least two operator actions (one of which shall serve as a laser arming control) required to cause the laser to function?	N/A	
26	Is laser output impossible when arming control is in the safe position?	N/A	
27	Is the laser fire trigger or switch clearly identified and physically protected to prevent accidental activation (when possible, the switch shall be a guarded positive action type that requires continuous operator intent to operate the laser product and laser output shall cease immediately upon release)?	N/A	
28	If the laser is pulsed, is the activation circuitry designed so that continual depression or short-circuiting of the fire control switch will not cause repeated emissions [unless necessary for the performance of intended function(s)]?	N/A	
29	If operational considerations preclude the use of a dead-man switch, a toggled switch may be used if adequate design safeguards are provided to prevent long-term inadvertent lasing (e.g., through a watchdog timer and/or system logic switching device). Are these employed?	N/A	Switch guard not tall enough to prevent accidental activation
30	Does the laser have a permanently installed/ attached exit port cover that prevents access by any part of the body to all laser radiation in excess of ANSI AEL for Class 1?	N/A	
30a	Does the cover chosen clearly indicate that it is in place (safe) or open?	N/A	
30b	Is the cover designed to withstand repeated laser firings when it is in either position?	N/A	
31	Is a readily available remote-control interlock capability incorporated on the laser or auxiliary power supply systems?	N/A	
31a	Does the remote control connector have an electrical potential no greater than 130 rms. V between terminals (not essential if the laser is always directed into an interlocked set enclosure for maintenance or service procedures)?	N/A	

Item	Requirement	Yes/No	Comment
31b	When the terminals of the connector are not electrically joined, is human access to all laser radiation and collateral radiation in excess of ANSI AEL for Class 1 prevented?	N/A	
31c	Is an intentional reset needed to reactivate the system once disconnected?	N/A	
32	Is the boresight alignment and retention designed consistent with system mission requirements (considered a safety-critical item)?	N/A	
33	Are laser status (emission) indicators (aural or visual or as specified by the procuring agency) provided to inform the operator when the laser is prepared to fire (armed) and when the laser is actually firing?	N/A	
33a	If visual indicators are used for operation or maintenance, are they visible during daylight, nighttime, and when viewed through appropriate protective eye wear?	N/A	
33b	Are indicators located so that viewing does not require personnel exposure to laser radiation in excess of the ANSI AEL for Class 1?	N/A	
34	Is there a means to differentiate between armed and firing (e.g. continuous tone or light is armed and intermittent tone or blinking light is firing)?	N/A	
35	If the laser system is installed on an aircraft, is it designed to prevent laser output while the aircraft is not airborne?	N/A	
35a	Is an override switch for ground maintenance designed to prevent inadvertent activation?	N/A	
36	Does the laser product incorporate controls to optimize positive operator control of beam pointing?	N/A	
36a	Does it include a means of ensuring boresight retention and software systems safety?	N/A	
37	For systems with automatic target tracking capability, is an automatic disable capacity incorporated to inhibit laser firing if target tracking outside the system specifications occurs or when the laser sight line reaches the gimbal limits or the system mask limit?	N/A	
38	If no hardware stops are installed, are at least two independent systems capable of disabling the laser (a provision to override these automatic features during combat is permitted)?	N/A	

Item	Requirement	Yes/No	Comment
39	For lasers using a beam scanning technique, if irregularities not normal to the operation and unintended pattern changes increase the hazard potential of the laser product, does it include a feature that terminates or reduces the beam output to ANSI AEL for Class 1 immediately upon the cessation of scanning irregularities (change in either scan velocity or amplitude)?	N/A	
40	If a training mode is required for the laser, are provisions made (beam attenuator, expander, diffuser or less-hazardous lasers, TV cameras, etc.) to reduce hazardous emissions to the lowest level consistent with training requirements?	N/A	
41	If the laser can be used in both a mission and a training mode, is a visual indication provided to inform the operator and outside observers that the laser is positively in the training mode?	N/A	
42	Have the system's Nominal Ocular Hazard Distance (NOHD), skin hazard distance, diffuse reflection hazard determination, protective eye wear requirements, buffer zone requirements, and safety parameters been certified by measurements by NSWCDD (Code G71) and approved by the LSRB?	Y	
43	Do aiming optics employ a reticle that can be viewed under any illumination conditions?	N/A	
43a	Does the reticle not impair dark adaptation of observer's eyes?	N/A	
43b	Is the reticle calibrated so the operator can determine the proximity of the laser beam to target buffer zones?	N/A	

SECTION 2 SUPPORT EQUIPMENT DESIGN REQUIREMENT CHECKLIST

Item	Requirement	Yes/No	Comment
1	**Items 1-7 are applicable to all classes of laser support equipment** If the laser support equipment is military exempt, is it used solely in support of exempted lasers?		
2	Is the laser support equipment designed to ensure that laser radiation emitted during maintenance or service is no greater than the ANSI AEL for Class 1 and that collateral radiation is not in excess of applicable limits, when practicable?		
3	Does the equipment confine the laser radiation within an opaque enclosure?		
4	Is the enclosure interlocked to prevent exposure to levels in excess of the ANSI AEL for Class 1 when the enclosure is removed?		
5	Is the enclosure provided with the appropriate exterior warning indicators and labels?		
6	Have other associated hazards been addressed and controlled by suitable engineering programs per MIL-STD-882, MIL-STD-2036, and SPAWARINST 4110.1?		
7	Are adequate instructions as to safe techniques and personnel protective means included in all technical manuals and plainly marked on the laser product when potentially hazardous areas are accessible?		
8	**Items 8-13 are applicable to Class 1, Class 2, and Class 3a laser support equipment requirements** Does the laser support equipment meet the design (performance) requirements of 21 CFR Class I, Class II, or Class IIIa, respectively, except where such requirements restrict operational capability or security?		
9	Does the laser support equipment meet designation and warning requirements of 21 CFR Class I, Class II, or Class IIIa, respectively, with the exception that the ANSI classification will be displayed in the lower right corner rather than the FDA class?		
10	Are labels permanently affixed or inscribed on such products as to be legible and readily accessible to view when the product is fully assembled for use?		

Item	Requirement	Yes/No	Comment
11	Are warning labels affixed to the housing in such a manner that viewing the label does not require personnel exposure to laser radiation?		
11a	Is numerical output information [e.g., wavelength(s) and maximum power output (when unclassified)] located along the lower edge in a smaller font?		
11b	Does the word **INVISIBLE** or **VISIBLE**, as appropriate, precede the word **RADIATION**?		
11c	When labels may compromise camouflage, are muted colors appropriate to the camouflage paint scheme used?		
11d	Is information classified in the interest of national security omitted from labels?		
12	When a laser has a defeatable interlock that, when defeated, allows access to Class 3b or Class 4 emission levels, is an additional label that states the following installed on or near the access panel? **DANGER** **Laser Radiation When Open and Interlock Defeated, Avoid Eye or Skin Exposure to Direct or Scattered Radiation.**		
13	Does non-exempted support equipment incorporate military labeling when alternate labeling has been requested by the manufacturer and approved as a variance by the FDA in accordance with 21 CFR 1040 (g)(10)?		
14	**Items 14-24 are Class 3b and Class 4 laser support equipment requirements** Does the laser system test equipment for boresight and laser performance testing attenuate the beam to limit personnel exposure to below AEL for ANSI Class 1?		
15	Is the laser system test equipment for boresight and laser performance testing interlocked to the laser to prevent inadvertent laser operation outside the enclosure if the test equipment is not used in a closed installation?		
16	Is an access interlock switch interfaced with ANSI Class 3b and Class 4 laser systems under test such that inadvertent removal of test sets or poor connection will terminate or limit the laser output to the ANSI AEL for Class 1 or Class 2, if applicable?		

Item	Requirement	Yes/No	Comment
17	Is a warning system activated immediately prior to operation of the laser and remain activated until the laser output has been reduced to the ANSI AEL for Class 1 or Class 2, if applicable?		
17a	Is the warning system designed not to attract personnel attention in such a manner as to create a potential hazard?		
18	Does all support equipment for laser hardware that could directly activate the laser preferably incorporate a positive action (dead-man) switch that must be activated when laser firing is desired?		
19	When a dead-man switch is not incorporated, is an emergency cutoff switch provided that allows emergency cutoff of laser output in excess of ANSI AEL for Class 1 or Class 2, as appropriate?		
19a	Is the switch readily accessible from the operator's position and permit one-step operation?		
20	Is a key-lock master switch provided to prevent unauthorized activation of any test facility component used to supply power directly to the laser that is necessary for its operation?		
21	Is the laser beam terminated by a beam stop that is diffuse (i.e., has a low value of reflectance at the laser wavelength)?		
21a	Is such a beam stop fire resistant and unable to emit toxic or carcinogenic fumes when exposed to the laser(s) for which it was designed?		
21b	Is the beam stop marked for the type(s) and power level(s) of laser(s) for which it is procured?		
22	Are appropriate control measures for the protection of personnel (e.g., appropriate exhaust ventilation) provided where toxic gases cannot be prevented, such as firebrick, which contains beryllium compounds?		
23	Are Class 3b and Class 4 laser support equipment, as defined by ANSI, provided with a label similar to the examples illustrated in Figure 2?		
23a	Are such labels permanently affixed or inscribed on such products to be legible and readily accessible to view when the product is fully assembled for use?		
23b	Is the label affixed to the laser system housing near the fire button and exit port when the port is remote from the operator in such a manner that viewing the label does not require personnel exposure to laser radiation?		

Item	Requirement	Yes/No	Comment
23c	Does the label use the word **DANGER** and include the type of laser and the word **VISIBLE** or **INVISIBLE** preceding the word **RADIATION**?		
23d	Does the label contain an appropriate instructional safety statement or control message for the operator or bystander as applicable? For Class 3b and Class 4 ground target designators: **DO NOT AIM AT PERSONNEL OR FLAT GLASS SURFACES** For Class 4 laser support equipment that present a diffuse reflection hazard: **DO NOT AIM AT PERSONNEL OR FLAT GLASS SURFACES OR TARGETS WITHIN ___ METERS** Bystander warning for wavelengths 400 to 1400 nm; Class 3b and Class 4 laser support equipment **DO NOT LOOK INTO PORTHOLE** Bystander warning for wavelengths 1400 nm to 1 mm and 180 to 400 nm; Class 3b and Class 4 laser support equipment: **DO NOT EXPOSE EYE OR SKIN TO DIRECT OR SPECULARLY REFLECTED BEAMS**		
23e	Do **DANGER** labels have **DANGER** printed upon a white background with a bright red oval around the word **DANGER** and contain a red starburst and black lettering?		
23f	When camouflage maybe compromised by such warning labels, are appropriate muted colors (i.e., olive drab) used?		
23g	If the information is unclassified, are the ANSI laser hazard classification, wavelength(s), and maximum radiant power or energy added along the lower edge of the label?		
24	Is laser output impossible when arming control is in the safe position?		

SECTION 3 LASER FACILITY DESIGN REQUIREMENT CHECKLIST

2.1.1.1.1	Requirement	Yes/No	Comment
1	Is support equipment designed such that laser radiation emitted during maintenance or service is no greater than the ANSI AEL for Class 1 and collateral radiation is not in excess of applicable limits when practicable?		
2	Can support equipment confine the laser radiation within an enclosure that is adequately interlocked to prevent levels in excess of ANSI AEL for Class 1 when the enclosure is removed?		
2a	Is the enclosure provided with appropriate exterior warning indicators and labels?		
3	Have other associated hazards been addressed and controlled by suitable engineering programs per MIL-STD-882, MIL-STD-2036, SPAWARINST 4110.1, and ANSI Z136.1?		
4	Are adequate instructions as to safe techniques and personnel protective means included in all technical references (manuals) and plainly marked on the laser product when potentially hazardous areas are accessible?		
5	Is facility designed for limited personnel access?		
6	Is facility a closed installation for Class 3b and Class 4 lasers?		
7	Are reasonably high illumination levels at the work areas attainable to overcome any reduction in visual performance primarily due to the use of laser protective eyewear?		
8	When practicable, is facility designed so that no personnel protective equipment is required?		
9	When the hands or other parts of the body are likely to be exposed to potentially hazardous levels, are protective coverings provided?		
10	Are all personnel working in laser facility provided with suitable personal protective clothing and equipment?		
11	Does laser protective eyewear provide complete protection for the individual's field-of-view and is it marked with the Optical Density (OD) at the specific laser wavelengths?		

2.1.1.1.1	Requirement	Yes/No	Comment
12	Is protective eyewear selected according to the laser equipment used at that facility?		
13	Is protective eyewear selected suitable for individuals requiring corrective lenses as well as for uncorrected vision?		
14	**Items 14-26 are applicable to Class 3b and Class 4 laser facility requirements** Is a laser warning sign displayed on all entry points or doors to the facility?		
14a	Do warning signs use the word **DANGER** and include the type of laser (**VISIBLE** and/or **INVISIBLE**), as appropriate, and precede the word **RADIATION**?		
14b	Do such warning signs contain an appropriate instructional statement; e.g., **KNOCK BEFORE ENTERING** or **KNOCK AND WAIT**?		
15	Are access interlock switches interfaced with ANSI Class 3b and Class 4 laser systems under test such that inadvertent entry into facility will terminate or limit the laser output to the ANSI AEL for Class 1 or Class 2?		
15a	Are these interlock systems such that inadvertent removal or poor connection of test sets will terminate or limit laser output to ANSI AEL Class 1 or Class 2?		
16	Is a warning system, external to the facility, activated immediately prior to operation of the laser and remain activated until laser output has been reduced to the ANSI AEL for Class 1 or Class 2, if applicable?		
17	Does the facility incorporate operation switches and beam stops per checklist items 24 through 31 for support equipment requirements?		
18	Does test equipment for boresight and laser performance enclose the beam to limit personnel exposure to below class 1 AEL?		
19	Is test equipment interlocked to laser to prevent inadvertent laser operation outside the enclosure if test is not in a closed installation?		

2.1.1.1.1	Requirement	Yes/No	Comment
20	Where the laser is not otherwise supported rigidly, is a mechanical fixture provided to rigidly attach the laser in a fixed position during testing and maintenance?		
21	Are location & orientation of test fixtures such that exposure of personnel to direct beam is minimized?		
22	Are the interior surfaces of the facility painted with a finish that has a low value of reflectance at the laser wavelength(s) and that will diffuse the laser beam while maintaining an acceptable ambient illumination?		
23	Are additional safety features to warn personnel to clear the beam path area and a low-power visible laser subsystem for pre-alignment provided?		
24	If the facility is designed for very high-power continuous wave (CW) or pulsed lasers, does it have a means to enclose the entire beam path within the facility?		
24a	Is the enclosure designed to withstand the direct beam?		
25	If necessary, are remote-control firing and television monitoring provided?		
26	Have associated hazards been controlled? Has ANSI Z136.1 requirements been incorporated?		

SECTION 4 LASER PROTECTIVE EYEWEAR CHECKLIST

2.1.1.1.2	Requirement	Yes/No	Comment
1	Does laser protective eyewear protect against the worst possible exposure situation?		
2	Does it allow the best compromise between protection and high visibility?		
3	Is protective eyewear fully compatible with normal corrective lenses (spectacles)?		
4	Does protective eyewear take into consideration all wavelengths emitted from the laser?		
5	Is wavelength range for which eyewear is designed clearly marked on the protective eyewear?		
6	Is the Optical Density (OD) at each wavelength for which the protective eyewear is designed clearly marked on the eyewear?		
7	Is the damage threshold intensity of the protective eyewear in excess of the maximum intensity emitted by the laser?		
8	Is the protective eyewear durable for the anticipated environment and lifetime?		
9	Has protective eyewear with curved lenses been considered?		