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DEPARTMENT OF DEFENSE HANDBOOK

USE OF HANDHELD LASERS TO REMOVE COATINGS AND CORROSION FROM AEROSPACE GROUND EQUIPMENT

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FOREWORD

1. This handbook is approved for use by the Department of the AIR FORCE and is available for use by all Departments and Agencies of the Department of Defense.

2. This handbook covers the application of handheld lasers used to remove coatings from aerospace ground equipment surfaces.

3. This handbook is approved for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

4. Comments, suggestions, or questions on this document should be addressed to: U.S AIR FORCE AFLCMC/EZPT-CPCO, 325 Richard Ray Blvd., Bldg. 165, Robins AFB, GA 31098-1639 or emailed to affcorr@us.af.mil. ASSIST related questions should be emailed to the agent at SPEC99@us.af.mil . Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

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1. SCOPE

1.1 Scope. This handbook establishes best practices for use of the *CleanLASER* handheld lasers (HHL), specifically models CL300 and CL1000, on aerospace ground equipment (AGE) for corrosion and organic coating removal. It is important to note that this handbook is note applicable to other commercial off the shelf hand held lasers, The handbook covers various topics including, but not limited to, safety, training, maintenance, troubleshooting, tools, materials, and operation of the HHL. This handbook is for guidance only and cannot be cited as a requirement.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are those needed to understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-PRF-131	Barrier Materials, Water Vapor Proof, Greaseproof, Flexible, Heat-Sealable

(Copies of this document are available online at https://quicksearch.dla.mil .)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein.

DEPARTMENT OF THE AIR FORCE

AFI 48-139	Laser and Optical Radiation Protection Program
TO 35-1-3	Corrosion Prevention and Control, Cleaning, Painting, and Marking or USAF Support Equipment (SE)

(Copies of the AFI are available online at https://www.e-publishing.af.mil and copies of the TO can be obtained from afcorr@us.af.mil .)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Z136.1	American National Standard for Safe Use of Lasers

(Copies of this document are available online at https://www.ansi.org .)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) INTERNATIONAL

SAE-AMS-T-23397 Tape, Pressure-Sensitive Adhesive, for Masking during Paint Stripping Operations

(Copies of this document can be obtained online at https://www.sae.org .)

3. DEFINITIONS AND ACRONYMS

3.1 Ablation. Method by which the laser removes corrosion and coatings; laser energy is absorbed by the corrosion and coatings causing them to separate from the substrate as small particulates. This is essentially a sublimation process whereby matter is transformed from the solid to gas phase.

3.2 Aperture lens. Lens that focuses the laser beam inside the end effector to a single spot that hits the surface.

3.3 *CleanLASER* HHL. A system that generates a laser beam by passing electrical current through a Neodymium-doped: Yttrium Aluminum Garnet (Nd:YAG) crystal inside of a resonator. The crystal excites electrons from electrical current out of their equilibrium state, and when they return to the ground state, light energy is emitted in the form of photons at 1,064 nanometers (nm) in wavelength. These photons then pass through a fiber optic cable to the end effector that the HHL operator holds.

3.4 Fiber optic cable. Cable by which the laser beam travels from the resonator to the end effector.

3.5 HHL end effector. A "gun-shaped" device that the HHL operator uses to direct laser energy onto the work surface. The trigger on the end effector is double pulled to actuate the laser.

3.6 Laser pulse. An individual blast of the laser beam from the resonator, through the fiber optic cable, and out the end effector. Duration of the pulse can be changed by altering pulse frequency. The pulsing of the laser is what causes ablation of the coating and corrosion to take place.

3.7 Plasma. A hot, ionized gas that is sometimes created at the point of ablation on the work surface.

3.8 Scanning mirror. A mirror inside the end effector of the HHL that moves the individual pulses of the laser back and forth in a one dimensional line.

3.9 Acronyms.

AF	Air Force
AFI	Air Force Instruction
AGE	Aerospace Ground Equipment
ANSI	American National Standards Institute
BEE	Bioenvironmental Engineer
CTK	Consolidated Tool Kit
DoD	Department of Defense
EMS	Electronic Margin Shielding
HEPA	High Efficiency Particulate Arrestance
HHL	Handheld Laser
ILSO	Installation Laser Safety Officer
Nd:YAG	Neodymium-doped: Yttrium Aluminum Garnet
NHZ	Nominal Hazard Zone
nm	Nanometer
NOHD	Nominal Ocular Hazard Distance
NSHD	Nominal Skin Hazard Distance
OD	Optical Density
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
SOP	Standard Operating Procedures
SPF	Sun Protection Factor
SPO	System Program Office
ULSO	Unit Laser Safety Officer
USAFSAM	United States Air Force School of Aerospace Medicine
UV	Ultraviolet
W	Watts

4. GENERAL GUIDANCE

4.1 General use of this handbook. This handbook is a supplement to other documents for how to properly operate and maintain the CL300 and CL1000 Watt (W) HHLs. Other documents to be used with this handbook include, but are not limited to, Installation Laser Safety Officer's (ILSO's) approved Standard Operating Procedures (SOP), Air Force Instruction (AFI) 48-139, American National Standards Institute (ANSI) Z136.1, and the *CleanLASER* operator and maintenance manuals.

4.2 Class. The CL300 and CL1000 HHLs are classified per ANSI Z136.1 as a Class 4 laser.

4.3 Description of the HHL. The HHL system is mounted on a cart (see Figure 1) for limited mobile operation. Each laser will be operated with the *TEKA* LFE 301 three-stage vacuum

filtration unit, which removes the particulates, gases, and vapors at the point of corrosion or coating removal.

FIGURE 1. *CleanLASER CL300 with TEKA LFE 301 vacuum system*

The laser beam is delivered via fiber optic to a manually operated end effector, such as the one shown in Figure 2. The black hose supplies suction to keep contaminants below the Occupational Health and Safety Administration's (OSHA) permissible exposure limits (PEL). The green line is the fiber optic cable that delivers the laser beam from the resonator to the work surface.

FIGURE 2: *Image of a 300W Hand-Held Laser End Effector with sensor package, vacuum hose connection, and fiber optic cable connection*

4.4 Approved applications. The HHLs are currently approved only for AGE applications and will not be used under any circumstances on other Department of Defense (DoD) equipment without prior approval from the weapon system program office (SPO).

4.5 HHL operational requirements/technical specifications. Technical specifications and power requirements for the HHLs can be found in Table I.

TABLE I. *CL300 and CL1000 power requirements and technical specifications*

Specification	Value
Wavelength	1064 nm
Laser Class	Class 4, Nd:YAG
Power Required	480V, 3 Phase, 50 or 60 Hz
Power Consumption	~5 kW/hr (300 W); ~7kW/hr (1000 W)
Compressed Air	45 psi
Temperature Range	40-104°F
Humidity Range	Less than 95% Relative Humidity
Size (L x W x H)	61" x 30" x 46" (300 W) 64" x 30" x 60" (1,000 W)
Weight	~485 lbs (300 W); ~1,080 lbs (1000 W)

4.6 *TEKA* LFE 301 vacuum specifications. Specifications associated with the *TEKA* LFE 301 vacuum unit can be found in Table II.

TABLE II. *TEKA LFE 301 specifications*

Item	Requirement
Primary Filtration	Dust Class BIA M
Activated Carbon	Granulated Activated Carbon
Final HEPA Filter Stage	Filter Class H13
Maximum Vacuum Hose Length	60 ft
Volumetric Air Flow	235 ft^3/min.

4.7 Coating and corrosion removal methodology. The HHL removes coatings and corrosion by an ablation process. The coatings and corrosion absorb the laser energy, which causes them to separate from the substrate. Heavy metals, such as cadmium, chromium, and lead, will not be ablated, but will rather remain in their particulate form. The vast majority of organic coatings, however, are hydrocarbon chains which will be ablated into carbon monoxide, carbon dioxide, and water. The particulates and gases generated during this process are captured by the vacuum and captured by the high efficiency particulate arrestance (HEPA) filtration system. The visible light seen above the surface when lasing is the result of invisible laser beam interacting with the particulates removed from the substrate. Figure 3 provides an illustration of the coating removal process.

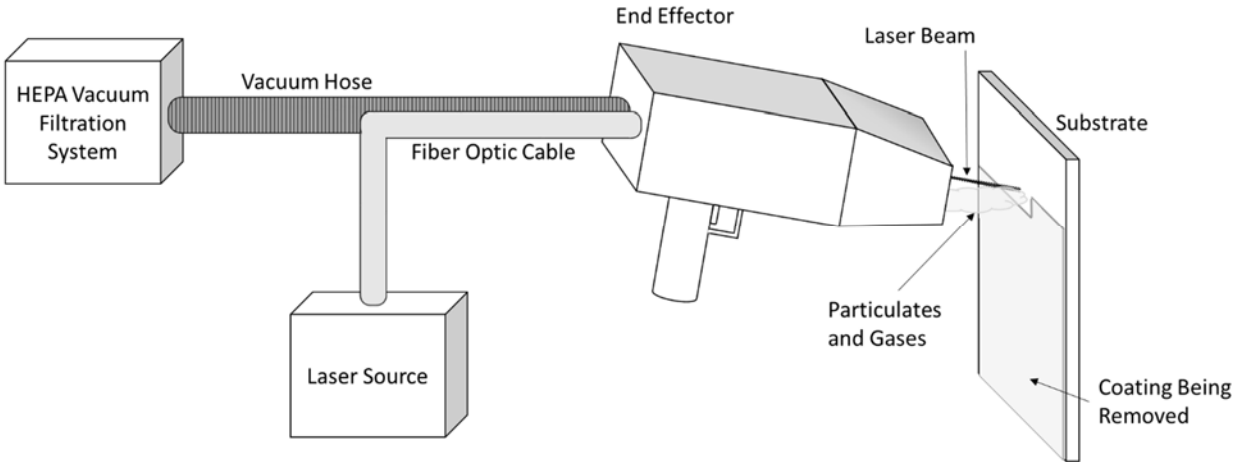

FIGURE 3. *HHL illustration of coating removal*

4.8 General safety requirement.

4.8.1 Unit Laser Safety Officer (ULSO). The ULSO will be assigned by a unit's fabrication flight. The ULSO will be trained by the ILSO to become familiar with both general laser safety requirements and requirements specific to the CL300 and CL1000. All operational personnel using the HHL will receive laser safety training at least once annually by the ULSO or other trained personnel.

4.8.2 Bioenvironmental engineering. The ILSO or base bioenvironmental engineer (BEE) may require additional training beyond the scope of this document. All laser operators will comply with these additional requirements prior to use of the HHL.

4.8.3 Qualified operators. Only personnel that have been trained by cognizant engineering authority and the ULSO may operate the HHL. Additionally, all HHL operators are required to obtain a baseline eye exam prior to using the laser or receiving hands-on training. Supervisors will work with public health and the ILSO to ensure the correct exam is performed and documented in the employee's occupational health record.

4.8.4 General HHL hazards.

4.8.4.1 Beam hazards and mitigation. The 1064nm wavelength HHL system is an ANSI Z136.1 Class 4 laser with an invisible beam that can cause temporary or permanent damage to the eyes or skin. The following steps will be used to mitigate beam-related hazards of the HHL. There may be additional requirements as defined by the ILSO.

4.8.4.2 Laser controlled area. A laser controlled area will be configured as outlined in 4.8.4.7.

4.8.4.3 Protective eyewear. The most critical safety requirement for operators, trainees, and others within the nominal ocular hazard distance (NOHD; see 4.8.4.6) is use of proper protective eyewear. Laser eye protection will be worn by all personnel within the laser controlled area during laser operation. Laser eye protection will be compatible with the type of laser being used. If more than one type of laser is operated in the facility, ensure the laser eye protection is the proper type

for the laser being used. The HHL requires laser eye protection rated for a wavelength of 1064 nm and an optical density of six or greater (OD 6+).

4.8.4.3.1 Selecting appropriate eyewear. To identify the protection rating of the laser eye protection, find all the wavelength ranges on the lens that include 1064 nm and identify the range with the highest optical density; this is the OD rating of the laser eye protection. Ensure the optical density is OD 6, OD 6+, or greater. An example of the wavelength range and optical density on laser safety glasses is shown in Figure 4.

FIGURE 4. *Laser eye protection rating with wavelength ranges*

4.8.4.3.2 USAFSAM approved protective eyewear. For the HHL, several types of laser eye protection have been approved for use by United States Air Force School of Aerospace Medicine (USAFSAM) and are listed in Table III. Final approval of these additional types of laser eye protection will be determined by the ILSO.

TABLE III. *USAFSAM approved laser eyewear*

300W Approved Frames	Manufacturer / Part Number	Lens Filters
	NoIR / # 50	YG4, YG5, DBD, or DBY
	NoIR / # 60	YG4, YG5, DBD, or DBY
	NoIR # 51 (Medium) NoIR # 53 (Large)	YG4, YG5, DBD, or DBY

4.8.4.3.3 Protective eyewear checks and maintenance.

a. Prior to use of the HHL, ensure the laser eye protection fits properly and that there are no defects in the eye protection such as lenses separating from the frames.

b. The lenses of the laser eye protection will be free of scratches, pitting, surface cracks, or discoloration as they may reduce the capability to filter the laser light. If the laser eye protection has been subjected to environmental stresses such as high temperature, caustic agents, etc., replacement will be considered.

c. The laser eye protection can be cleaned with a mild soap and water. Typical lens cleaning solutions, such as isopropyl alcohol, will not be used.

d. If the laser eye protection fogs during operation, stop working and clean. If cleaning requires removal of eye protection, ensure laser is off and clean or replace laser eye protection. Do not continue operating the hand-held laser system while vision is impaired. Find a pair or style of laser eye protection that does not impair vision while operating the HHL.

4.8.4.4 Skin protection. The plasma generated during the laser ablation process produces ultraviolet (UV) light. This is the same type of UV exposure that is experienced from solar radiation. It is recommended that the following steps be taken to protect operators with sensitive skin while using the HHL. As users become familiar with the HHL, they will see what their exposure limits are and can tailor the recommendations in 4.8.4.4.1 and 4.8.4.4.2 for their specific scenario.

4.8.4.4.1 Use of clothing to prevent UV exposure. Gloves (leather, nitrile, Nomex® flight glove, or equivalent) and long sleeves may be used to prevent UV exposure to the arms and hands.

4.8.4.4.2 Use of sunscreen to prevent UV exposure. Users may also use UVA/UVB sunscreen to prevent exposure to UV radiation. This is beneficial for the neck and face, as well as for the arms and hands in a hot environment where long sleeves inhibit user comfort. Sunscreen for use with the handheld laser will have a minimum sun protection factor (SPF) of 30.

4.8.4.5 Non-beam hazards and mitigation. Several non-beam hazards exist; these hazards are listed in 4.8.4.5.1 through 4.8.4.5.6 and are mitigated by the design of the HHL, local engineering controls, personal protective equipment (PPE), and procedural controls defined throughout this handbook.

4.8.4.5.1 Electrical hazards. Electrical hazards exist due to high voltage internal to the HHL. Except for what's allowed by the original equipment manufacturers (OEM) manuals, only the OEM or one of the OEM's distributors will service or troubleshoot electrical components.

4.8.4.5.2 Heat. Heat generated by processing the surface may cause burns if operator's skin contacts an area that was recently treated with the HHL. Light reflecting off processed surfaces can cause slight heating of the operator's skin. This can be mitigated by re-angling the end effector or by the operator changing positions to prevent direct reflectance.

4.8.4.5.3 Fire hazard. Do not use the HHL when flammable vapors are present. The HHL will not be used or powered on within 20 feet of designated paint mixing areas, open spray booths, or within three feet of any opening to an enclosed spray booth, if painting. Flammable/combustible materials (solvents, paper, and cardboard) will be removed from the laser area or shielded when possible. Laser safety curtains or shields will be used that are approved by the ILSO. If flammable/ combustible greases, hydraulic fluids, or fuels are present on the surface to be lased, remove as much of the material as possible with an approved removal method.

4.8.4.5.4 Noise. The noise levels associated with operation of the HHL are below actionable limits required to wear hearing protection. However, hearing protection may be required when using the HHL if other noises generated by equipment in the immediate area combine to exceed actionable limits. The BEE/ILSO is responsible for determining if hearing protection is required.

4.8.4.5.5 Laser generated air contaminants. Air sampling testing performed by USAFSAM has shown the *TEKA* LFE 301 vacuum/filtration system is effective in capturing all contaminants and that respirators are not required while operating the HHL. The local BEE/ILSO is responsible for this determination at the base level and may require further testing. When performing preventative maintenance on the filtration system, such as changing filters or emptying the dust collection drawer, a respirator will be worn along with any other personal protective equipment required by the local bioenvironmental office.

4.8.4.5.6 Ergonomics. Ergonomics of the HHL is comparable to other paint removal processes, such as sanding and blasting. Users will maintain a comfortable position whenever possible. Allowing the fiber optic cable and vacuum hose to rest on the operator's shoulder helps support the weight of the end effector to facilitate more comfortable operation of the HHL.

4.8.4.6 Nominal Hazard Zone (NHZ). The NHZ is the space within which the level of radiation released from a laser or reflected from surfaces could exceed the maximum permissible exposure level and cause health and safety concerns to workers or bystanders. The nominal ocular hazard distance (NOHD) and the nominal skin hazard distance (NSHD) for the 1064 nm wavelength hand-held pulsed fiber laser with no protections put into place are shown in Table IV.

TABLE IV. *NOHD and NSHD for the CL300 and CL1000 HHLs*

Laser System	Laser NOHD	Laser NSHD
CleanLASER CL300: 1064 nm Pulsed Fiber Hand-Held Laser with OSH50 End Effector	105 feet	6 feet
CleanLASER CL1000: 1064 nm Pulsed Fiber Hand-Held Laser with OSH80 End Effector	171 feet	13 feet

4.8.4.6.1 NHZ of enclosed room. When used in an enclosed room where there is no opportunity for the laser beam to escape, the NHZ is the space inside the closed room. In order for this to hold true, all cracks will be sealed, solid walls (concrete, industrial sheet metal, wood) will be in place, the room will be fully closed off, and all windows will be either covered with

aluminum masking or the windows will be made of laser safety glass that prevents 1064 nm wavelength transmission.

4.8.4.6.2 NHZ of shielded environment. When used with laser-rated curtains and other barriers, such as walls, the NHZ is both the space within the curtains/walls and the space above the curtains extending line-of-site the distance of the nominal ocular hazard distance (NOHD). This requires operators of the HHL to be cognizant of catwalks, facility workers in the area that may be working on ceilings or on ladders.

4.8.4.7 Laser controlled area. Users will use the HHL in a controlled area designated by the ILSO. Considerations for the space are described in 4.8.4.7.1 through 4.8.4.7.4.

4.8.4.7.1 Safety interlocks. The HHL has a safety interlock port that can be used to connect the HHL to a door's interlock switch. The interlock interrupts the laser beam if the door is opened during operation. Dedicated laser rooms will have the rooms' door(s) interlocked with the laser. Temporary rooms may have laser safety curtains, beacons, and signs protecting the entrance(s).

4.8.4.7.2 Room walls. If any portion of the walls is combustible (paint booth filters in a paint booth), then remove or cover them with laser safety curtains or other appropriate shielding. Paint booth filters are not considered walls for a laser controlled area as they do not offer adequate protection against beam transmission.

4.8.4.7.3 Signs and beacons. Laser controlled area signs and beacons will be posted at the entryway(s) of the laser controlled area. The laser safety beacon will be positioned next to each sign and activated so it is visible by people approaching before they enter the laser controlled area when the laser is in operation. All personnel that work around the laser controlled area will be briefed on the significance of the signs and beacons. An example of a laser controlled area sign can be found in Figure 5.

FIGURE 5. *Sample laser controlled area sign*

4.8.4.7.4 Outdoor use. Do not use the HHL outdoors without all appropriate approvals. The NHZ is greater outdoors than indoors. Contact the ILSO and flight safety well in advance to seek approval.

4.8.4.8 HHL Access Control. The key to the laser control panel will be controlled, and only checked out to trained operators. The key will not be left unattended to prevent unauthorized use.

4.8.4.9 Visitors.

4.8.4.9.1 Approval. Visitors and spectators will be approved by the supervisor or someone higher in the chain of command. Verbal approval is sufficient.

4.8.4.9.2 Safety briefing. Qualified users will provide visitors with a safety briefing and PPE. As a minimum, visitors will be briefed on safe work practices, specific hazards, and emergency response procedures in the event of a suspected overexposure to laser radiation.

4.8.4.9.3 Protective eyewear. Both the visitor and a qualified laser technician will inspect the laser eye protection before the visitor puts on the laser eye protection. Visitors will wear protective eyewear at all times when inside the laser controlled area.

4.8.4.10 ANSI Z136.1. Compliance with ANSI Z136.1 control measures is mandatory. A list of these control measures can be found in Appendix A.

4.8.4.11 Standard operating procedures. An SOP is required per ANSI Z136.1 and will be available in the laser work area at all times. Within the SOP, a Pre-Use, Startup, and Shutdown

Checklist will be incorporated to ensure all safety criteria are met. A sample SOP with a Pre-Use, Startup, and Shutdown Checklist can be found in Appendix B.

4.9 Materials, tools, and equipment.

4.9.1 Recommended consumables. The recommended consumables to keep on hand for the CL300/1000 and *TEKA* LFE 301 can be found in Tables V and VI.

TABLE V. *Recommended spare parts to keep on-hand for CL300/1000*

Item	Part Number	Quantity	Notes
OSH 50 Protective Glass	1001894	5	CL300 Only
OSH 80 Protective Glass	1002849	5	CL1000 Only
Dryer Medium	1001911	10	
50 µm Coolant Filter	1009554	2	
Cleancool	100022213	2 gal	6 Month Shelf Life
Grease-free Optic Wipe or Swab	Source Locally	50	
Dry Isopropyl Alcohol	Source Locally	100 ml	
Latex/Nitrile Gloves	Source Locally	1 box	

TABLE VI. *Recommended spare parts to keep on-hand for TEKA LFE 301*

Item	Part Number	Quantity
LFE 301 Cartridge Filters	10025	1
HEPA cassette for LFE 301	100350004	1
Activated carbon refill including filter mats	97509	1

4.9.2 Preparation and masking materials. Table VII contains a list of commonly used preparatory and masking materials.

TABLE VII. *Appropriate masking agents and chemicals for surface preparation*

Nomenclature	Specification/Part Number/NSN	Purpose
Aluminum Tape (size as needed)	SAE-AMS-T-23397 or equivalent; 7510-00-473-9513	Masking
Aluminum Foil (size as needed)	Note: Do **NOT** use MIL-PRF-131 Aluminized Barrier Paper. 9535-00-684-4668 and 9535-00-242-5665	Masking
Cleaning Agents	Any approved solvents or detergents in TO 35-1-3 or the AGE OEM's maintenance manual	Surface Preparation/Cleanup

4.9.3 HEPA vacuum filtration system tool list. Table VIII contains a list of materials and tools for performing preventative maintenance on the HEPA vacuum filtration system. See the *TEKA* LFE 301 maintenance manual for more specific requirements on the maintenance of this unit.

TABLE VIII. *Maintenance tools for the TEKA LFE 301*

Item	Quantity	Purpose
Filter cartridges, dust class BIA M	1	Laser generated air contaminants removal
Activated carbon kit	1	Laser generated air contaminants removal
Final filter stage, filter class H13	1	Laser generated air contaminants removal
8 mm hex key	1	Opening filter compartments
Flathead screwdriver	1	Draining condensate

4.9.4 Safety equipment. Table IX contains required safety materials to properly use the HHLs in accordance with ANSI Z136.1.

TABLE IX. *Minimum safety materials required for HHL use*

Item	Manufacturer / Part Number / NSN	Use
Laser eye protection	NoIR / # 50, 51, 53, 60 frames with filters YG4, DBD, YG5 or equivalent that provide protection of OD 6 or higher for 1064 nm laser	Eye protection
Laser safety curtains (if applicable)	Any with a minimum 200 W/cm^2 power density at a minimum beam size of 5 mm for 100 seconds	Establishing laser controlled area
Laser controlled area sign	Local purchase per ANSI Z136.1	Establishing laser controlled area
Laser controlled area beacon	Local purchase per ANSI Z136.1	Establishing laser controlled area

4.10 Waste management.

4.10.1 Residual dust. The filtration systems are efficient in capturing the particulates and laser-generated air contaminants; however, residual dust may remain on the surface after the laser removed a coating or corrosion processing. It is recommended that surfaces containing residual dust be vacuumed with the laser system's HEPA filtration system, a shop vacuum with HEPA filter, or solvent wiped. Surrounding work areas will be cleaned as needed. Residual dust may contain hazardous materials, such as hexavalent chromium. Cleaning materials will be placed in an appropriate waste stream as defined by the local bioenvironmental office.

4.10.2 Filtration system filters. The filtration systems will require dust collection drawers to be emptied and filters to be changed periodically based on system use. The dust in the filtration system may contain hazards such as chromium VI from ablated primers. The dust and filter from the filtration system will be placed in an appropriate waste stream as defined by the local bioenvironmental office. Proper PPE will be worn when changing the filters. Consult with the local BEE to determine what PPE is required for changing filters.

4.10.3 HHL coolant and coolant filters. The coolant and coolant filters will be changed per OEM's guidelines. The coolant used in the HHL is glycol-based. The coolant and coolant filters will be disposed of in an appropriate waste stream as defined by the local bioenvironmental office.

4.10.4 Other waste materials. Other materials such as, but not limited to, the dryer medium, optical cleaning swabs, and masking materials that are not contaminated with hazardous materials do not require any special waste streams; however, if materials such as masking material or optical cleaning swabs are suspect of containing hazardous contaminants, they will be disposed of in the appropriate waste stream. Final disposal determination of any waste material, including anything not covered in this document will be determined by the local bioenvironmental office.

5. DETAILED GUIDANCE

5.1 Preparation of equipment and facilities.

5.1.1 Approved equipment. Ensure the equipment to be stripped is an approved candidate for HHL stripping (see 4.4).

5.1.2 Clean work area. The work area will be clear of all removable flammable/combustible materials. The HHL is a directed energy source that can be used as an ignition source. If flammable/combustible materials are unable to be removed from the area, the materials will be shielded using approved methods, such as laser safety curtains.

5.1.3 Fire extinguisher. Ensure a CO_2 fire extinguisher is within the laser hazard area for any emergencies.

5.1.4 Masking. Mask areas that need protecting from laser stripping with aluminum tape or aluminum foil. Do not use MIL-PRF-131 barrier paper because it contains plasticizers and will melt. The following areas will be protected from the laser:

a. Plastic components within the vicinity of lasing.

b. Wiring within the vicinity of lasing.

c. Any non-metallic components.

d. Metallic components not wishing to be stripped, such as data plates.

e. Other components not desired to be stripped, such as adhesive decals.

f. Out of focus items that may be hit by the HHL, such as the beam going through vents.

5.1.5 Laser controlled area. Ensure all safety precautions are in place and a laser controlled area has been established in accordance with 4.8.4.7. Ensure the laser beam cannot escape the controlled area. Everyone within the laser controlled area will be wearing appropriate protective equipment to protect from exposure.

5.1.6 Laser signs. Ensure laser safety signs are posted and visible to people approaching from all directions (see 4.8.4.7.3).

5.1.7 Beacons. Ensure laser safety beacons (see 4.8.4.7.3) are placed near every sign, and activate the beacons prior to lasing.

5.2 HHL and vacuum preparation for operation. Perform the following steps with the nozzle removed and the power off prior to startup of the HHL or *TEKA* LFE 301 vacuum system.

1. Inspect the HHL for damage, wear, leaks, etc., paying special attention to the umbilical cord that encases the fiber optic cable and the end effector.
2. Connect the HHL power cord to the power receptacle.
3. Connect the compressed air line to the HHL. Ensure the pressure going from the air line to the HHL is set at 45 psi and is supplying clean, dry air through an oil/water separator.
4. Connect the *TEKA* LFE 301 power cord to an appropriate power source. Note that a receptacle for the vacuum system is available on the HHL.
5. Connect a compressed air line to the vacuum system. Ensure the pressure going from the air line to the vacuum is set at 45 psi and is supplying clean, dry air through an oil/water separator. Note that a splitter can be used on the downstream side of the oil/water separator to supply 45 psi air to the HHL and vacuum system simultaneously.
6. Inspect end effector cover glass. If dirty, clean the glass using dry, isopropyl alcohol and grease-free optical cleaning paper per Table V. If unable to clean, replace per the OEM's maintenance instructions.
7. Inspect the end effector nozzle to ensure no obstructions are present. If obstructions are present, clean the nozzle.
8. If using the HHL in an enclosed room with interlocks, ensure the interlock connector is connected to the appropriate receptacle on the laser unit.

5.3 HHL startup. Complete following steps in the order they are listed.

1. Ensure the emergency stop button on the HHL control panel is in the up (released) position.
2. Insert the key into the HHL.

3. Turn the key clockwise to the "ON" position. Note that HHL startup time varies with environmental conditions. When the laser is ready, the main menu display screen will read, "Ready".

4. Check the display screen for error or warning messages. Address error or warning messages by clicking on the message. Address the error and then press, "Resolve".

5.4 Vacuum startup. Complete the following steps in the order they are listed.

1. Inspect the vacuum hose for any damage. If any damage is present, replace the hose.

2. Power the vacuum system by pressing and holding the power button until the system turns on.

3. Check the vacuum system screen for any warnings. Warnings will be addressed prior to operating the vacuum system. Address any warnings in accordance with the OEM's operating manual.

4. Connect the vacuum hose to the end effector and ensure there is suction at the end effector nozzle.

5.5 HHL settings and readying for use.

5.5.1 Laser eye protection. Prior to operating the HHL, ensure everyone is wearing the appropriate laser eye protection or other PPE as required.

5.5.2 Laser activation. Select the 300W or 1000W button on the touchscreen display to activate the laser. The light on top of the HHL should turn red, signifying the laser is ready to be fired.

5.5.3 Pulse frequency. Use the touchscreen display to select the desired pulse frequency. If unknown, start at the highest pulse frequency. Higher pulse frequency is proportional to lower pulse intensities.

5.5.4 Scan frequency. Adjust the scan frequency by moving the "scan" knob on the end effector. The ideal scan frequency should provide approximately a 50% overlap from one pulse to the next. Scan frequencies set too high will leave spaces between the pulses and result in inefficient coating and corrosion removal. Scan frequencies too low will result in over-ablation and also be inefficient because time and power is being expended on surfaces that may already be clean. If unsure of the scan frequency, start at 80 Hz, a setting of "2" on the knob.

5.5.5 Scan width. Adjust the scan width by moving the "width" know on the HHL end effector. The scan width should be appropriate for the amount of stripping that needs to take place. For example, if a small width needs to be stripped, such as a weld, setting the width to the area needs to be scanned will maximize efficiency by not expensing energy in undesired locations.

5.6 HHL operation.

5.6.1 Firing the laser. Aim the laser at the intended substrate, pull the trigger twice and hold down the laser, and begin moving the laser back and forth slowly until the corrosion and/or coating

is removed. When the end effector is emitting the laser beam, the red beacon on top of the HHL will begin flashing. The user should notice the sound of the ablation taking place. This will signify that the user is at the appropriate standoff distance.

5.6.2 Angling the end effector. When using the laser, keep the laser end effector at an 80° angle as much as possible to the surface being treated. Any other angle will be less efficient. See Figure 6 for an example of the proper end effector angle. Avoid holding the laser at a 90° angle as this results in some laser energy being reflected back into the end effector and prolonged use at a 90° angle may eventually cause damage inside the end effector.

FIGURE 6: *Proper end effector angle during HHL operation*

5.6.3 Checking the end effector glass. To avoid accidental exposure, power down the system and check the end effector glass and nozzle for dirt or deposits build-up hourly or as needed. The glass or nozzle will be cleaned if dirt or build-up is found. The frequency of this cleaning will depend upon the quantity and type of coating or corrosion being removed. Refer to 5.2 for cleaning instructions. If the end effector glass or nozzle is dirty, clean in accordance with this handbook or the OEM's manuals.

5.7 Shutting down the vacuum system.

5.7.1 Residual contaminants. Allow the vacuum system to run for a minimum of five minutes after discontinuing HHL operation. This allows residual contaminants to be removed prior to shut down.

5.7.2 Vacuum system shut down. Power the vacuum system down by holding the power button until the unit shuts off.

5.8 Shutting down the HHL.

5.8.1 Laser deactivation. Select the "0W" button on the touchscreen display to deactivate the laser.

5.8.2 Turning off the laser. Turn the key counter-clockwise to the OFF position. The laser system takes several seconds to fully power down. Remove the key from the laser and return it to the consolidated tool kit (CTK). DO NOT UNPLUG THE HHL UNTIL IT HAS FINISHED ITS SHUTDOWN PROCEDUE. Failure to do so could damage the laser because the HHL needs adequate time to cool off prior to shut down.

5.8.3 Storage. Unplug the laser system and store the umbilical and power cords on their storage racks, being careful not to kink or bend the umbilical too tightly. Bending the umbilical too tightly could damage the fiber optic line.

5.9 Verification and validation of the HHL.

5.9.1 Verification/validation frequency. The verification and validation of the HHL and filtration system will be performed when new equipment is received, as well as annually by the OEM or distributor to ensure the equipment is functioning properly.

5.9.2 Power. Power verification can be performed by trained operators viewing the main screen after running the HHL. The default screen will display the laser power when the HHL is on and operating. No external power meter is necessary. Additional power verification will be performed yearly by OEM or distributor service personnel during routine maintenance

5.9.3 Scan width. A calibration may be done to ensure the scan width number is accurate when the HHL is received, as well as at any time when the actual width is in question. The procedures below outline how this calibration is performed.

1. Obtain a flat painted panel approximately 12” x 12”. Procure a measuring device with mm units. The items captured in Table X are required to perform the validation of the laser’s scan width. Once the items are obtained, perform the steps in the order they are listed.

TABLE X. *Items needed for scan width validation*

Item	Source	Quantity
Metric scale or rule to measure mm	CTK	1
Flat metal panel appx 12” x 12”, with coating in accordance with MIL-PRF-85285, Type IV, Class H, Color 26173 or 36118	Varies: Scrap parts bin, paint shop, etc.	1

2. Place the painted panel on a flat surface.
3. Turn on the hand-held laser and filtration system per Sections 8 and 9 of this document.
4. Turn the “Width” knob on the end effector to the first setting outlined in Table XI or XII.
5. Perform one pass approximately 1 second, six inches in length over the painted panel.
6. Measure the width of the laser’s scan path and record it in the “Actual Width” column of the worksheets shown in Tables XI and XII.
7. The scan width should measure within ± 2 mm of the displayed width on the touchscreen.
8. Repeat steps 2 – 7 at all scan widths outlined in Tables XI and XII.
9. If the scan width is not within the expected range, notify the distributor of the unit.

TABLE XI. *Worksheet for checking scan width of CL300*

Scan Width Knob Position	**Expected Width in mm (± 2 mm)**	**Actual Width**
Min	4	
1	6	
2	13	
3	17	
4	23	
5	28	
6	35	
7	41	
8	47	
9	51	
Max	54	

TABLE XII. *Worksheet for checking scan width of CL1000*

Scan Width Setting	**Expected Width in mm (± 2 mm)**	**Actual Width**
12	12	
20	20	
30	30	
40	40	
50	50	
60	60	
70	70	
80	80	

5.9.4 Electronic margin shielding (EMS). The EMS setting is found only on the CL300 laser and is an optional feature which may not be present on all systems. This feature will be checked during the annual maintenance performed by the OEM or distributor.

5.9.5 Spot size/focal point of wheeled nozzle: The focal point on the surface can be changed by adjusting the wheels on the end effector nozzle. The focal point may change over time without the operator's knowledge if the screws on the wheels are not tightened properly or the nozzle is dropped. The focal point is set by the distributor when the laser is received, and checked during the annual maintenance. Operators may check and adjust the focal point of the nozzle if they suspect the focal point has changed.

5.9.5.1 Spot size/focal point check procedures. Use the following procedures to check the spot size and focal point.

1. Place the painted panel (see Table X) used for checking scan width on a flat surface.
2. Turn on the hand-held laser and filtration system per 5.2 of this document.
3. Set laser to lowest laser pulse frequency, highest scan frequency, and largest scan width.
4. Perform one pass approximately 1/10 of a second, six inches in length of the end effector over the painted panel. This is much faster than normal operation so that all the laser lines are spread out. The pass should look similar to the picture in Figure 7. It should be noted that individual spots may or may not be seen. If spots are not present, the line may be measured.

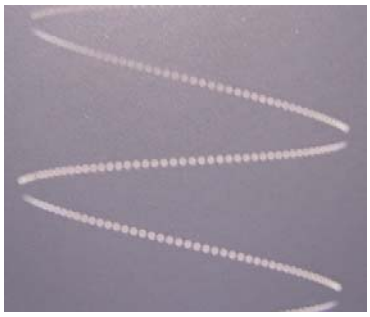

FIGURE 7. *Spot size and focal point check picture*

5. Mark the end effector nozzle to indicate the initial wheel position.
6. Adjust the wheels on the end effector nozzle up and down in 2 mm increments. The wheel height can be adjusted by loosening the two screws located on the nozzle. An image of these screws is captured in Figure 8.

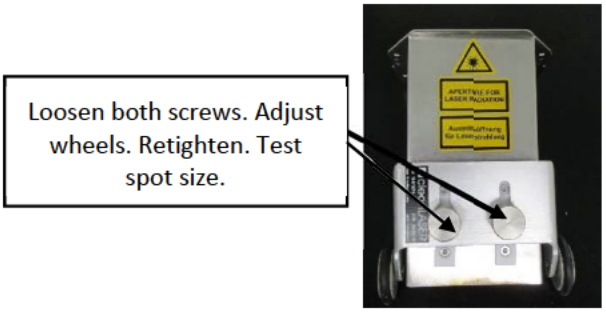

FIGURE 8. *Image of end effector nozzle with positioning screws identified*

7. At each increment move the gun with laser activated over several inches of the painted panel, much faster than normal operation so that all the laser spots are spread out.

8. Record the wheel filtration-nozzle position on the panel and measure the spot size with the calipers or optical micrometer. It should be noted that if individual spots are not seen the width of the line may be measured.

9. Once the minimum spot size is apparent move the wheels back to where the minimum spot size was obtained and tighten the fasteners. Mark this location with a permanent marker.

5.9.6 Scan frequency. The scan frequency can be adjusted and is verified by the HHL manufacturer or distributor. No verification is needed from the operator.

5.9.7 Laser pulse frequency. The laser pulse frequency can be adjusted by the operator and is verified by the HHL manufacturer. No verification is needed from the operator.

5.9.8 Filtration system. If the filtration system no longer pulls a vacuum, particulate leakage on the filtration unit may be the culprit, and the filtration system should be checked for proper function, filter life, and proper sealing per the vacuum manufacturer's manual. The HHL will not be used if the filtration system vacuum is not working properly. If issues cannot be resolved, the OEM or distributor should be contacted. These checks may need to be performed by personnel with hazmat and respirator training.

5.10 Preventative maintenance.

5.10.1 Preventative maintenance of the HHLs. Preventative maintenance for the HHLs will be accomplished as outlined in Tables XIII and XIV or the OEM's maintenance manual.

TABLE XIII. *HHL End effector preventative maintenance*

Maintenance Action	Frequency
Check the nozzle for collection of particulates in the intake and clean as needed	Before use and mid-day; or more often if excessive particulates are noted during use. Subject to change depending upon use.
Inspect the protective glass in the end effector for cleanliness. If contamination is present, clean the glass.	Before use and mid-day or more often if excessive particulates are noted during use. Subject to change depending upon use.
Change end effector protective glass.	If glass cannot be cleaned or if coating on protective glass is damaged.

TABLE XIV. *HHL Preventative maintenance*

Maintenance Action	Frequency
Run the unit (power on, so chiller circulates) for 30 min.	Weekly
Change coolant	6 months
Change the coolant particle filter	6 months and when filter change warning is displayed.
Full system inspection, service, and cooling system disinfect	Annually. To be performed by OEM or distributor.
Change the dryer medium in the resonator.	Per system warning “humidity error”.
Disinfect the chiller	Annually. To be performed by OEM or distributor.

5.10.2 Preventative maintenance for the vacuum system. Preventative maintenance for the TEKA LFE 301 vacuum system will be accomplished as outlined in Table XV or the OEM's maintenance manual.

TABLE XV. *Preventative maintenance requirements for the vacuum system*

Maintenance Action	Frequency
Check the fill level of the dust collection container. Empty if filled to 25% capacity.	Subject to amount of laser use.
Drain any condensation that has collected from the compressed air.	Weekly; subject to amount of HHL use and quality of compressed air.
Inspect the filter unit and connections for damage	Weekly
Inspect both ends of the vacuum hose for restrictions or blockages. Remove if present.	Weekly
Inspect the compressed air lines and connections by listening for any leaks.	Weekly
Replace the activated carbon cartridge	When replacing the final filter stage or when gasses/odors appear on the down-stream clean air side.
Check the cooling air filter for soiling level. Wash or replace if soiled.	6 months
Check the soiling level of the electronics filter mat (filter for the fan for the electronics). Wash or replace if soiled.	6 months
Test the electrical lines and grounding connections.	Annually
Particulate Filter Cartridges	Replace when "Suction Power Too Low" error occurs.
Final Filter Stage	Replace when "Suction Power Too Low" error occurs.

6. NOTES

6.1 Intended use. This handbook provides the guidance for operating and maintaining the CL300 and CL1000 W HHLs manufactured by *CleanLASER*. It is important to note this handbook is not applicable to other commercial off the shelf hand held lasers. This document is intended for use in conjunction with other applicable documents, such as the OEM maintenance and operational manuals, ANSI Z136.1, AFI 48-139, and other local base regulations and requirements

6.2 Subject term (key word) listings.

Cadmium
Carbon dioxide
Carbon monoxide
CleanLASER
CL300
CL1000
Hexavalent chromium
HHL (Handheld laser)
Isopropyl
Lead

APPENDIX A

HHL CONTROL MEASURES FROM ANSI Z136.1

A.1 SCOPE

A.1.1 Scope. This Appendix governs the requirements for how Class 4 lasers are to be controlled via physical or engineering methods to prevent injury to users or those in the laser controlled area. These requirements are governed by ANSI Z136.1 and shll be complied with Table A-I unless superseded by local base bioenvironmental or laser safety personnel.

TABLE A-I. *Class 4 control measures per ANSI Z136.1*

Control Measure	Class 4 Requirement	*CleanLASER* CL300 and CL1000 Compliance
Protective Housing A protective housing will be provided for all class of lasers or laser systems…	Shall	Laser generator is contained in a protective housing.
Interlocks on removable protective housings	Shall	Protective housings have interlocks.
Service Access panel	Shall	The panel allowing service personnel to access radiation area is interlocked. The service panel allowing access to high voltage requires both a removal tool and has a warning label.
Key Control	ANSI guidance is “Should”; however, OSHA requirement is “Will”	Key is controlled in the tool room. SOP requires that key can’t be left in laser unattended.
Viewing windows, display screens and diffuse display screens	Ensure viewing limited <MPE	Complies.
Collecting Optics	Shall	There are no collecting optics (lenses, telescopes, endoscopes, binoculars and or eye-loupes) used with these lasers.
Fully Open Beam Path	Shall	ULSO conducted a laser hazard evaluation and controlled area and NHZ are required by the SOP.

TABLE A-I. *Class 4 control measures per ANSI Z136.1* – Continued.

Control Measure	Class 4 Requirement	*CleanLASER* CL300 and CL1000 Compliance
Limited Open Beam Path	Shall	N/A. This system Complies with Fully Open Beam Path requirements.
Enclosed Beam Path	Further controls not required if 4.4.2.1 and 4.4.2.1.3 fulfilled	N/A
Area Warning Device	Shall	SOP includes beacon and sign requirements.
Emergency Conditions	Shall	The emergency stop button is red and labeled as “EMERGENCY STOP.”
Laser Radiation Emission Warning	Shall	Laser is equipped with red light to indicate when radiation is being emitted. The warning lights at each location of the warning signs will also be on and functioning.
Class 4 Laser Controlled Area	Shall	SOP indicates approved laser controlled areas and procedures to be used.
Entryway Controls	Shall	SOP indicates proper use of entryway control areas and procedures to be used. Laser systems have interlock connections which can be used.
Protective Barriers and Curtains	Should	SOP indicates protective barriers and curtains to be used.
Standard Operating Procedures (SOP)	Shall	An example SOP is provided with this process order. A location specific SOP will be approved by Installation LSO and kept with the laser.
Output Emissions Limitations	ILSO/ULSO Determination	N/A. Excessive power or radiant energy is not accessible during operation.

TABLE A-I. *Class 4 control measures per ANSI Z136.1* – Continued.

Control Measure	Class 4 Requirement	*CleanLASER* CL300 and CL1000 Compliance
Education and Training	Shall	All shop personnel receive annual laser safety training. Operators are trained and signed off in training records before using the laser unsupervised.
Authorized Personnel	Shall	Tool Room will only check out key to authorized personnel. SOP and AF training guidelines ensure only qualified individuals will service the machine. There are no user serviceable parts in the laser generator; this maintenance is performed by OEM. Users can change filters and clean lenses, etc.
Indoor Laser Controlled Area	Shall	SOP requires laser controlled area and defines the approved areas and procedures.
Class 4 Laser Controlled Area	Shall	SOP requires laser controlled area and defines the approved areas and procedures.
Temporary Laser Controlled Area	No Requirement	N/A
Controlled Operation	Should	Not applicable; uses a hand-held device that is controlled by the operator at the point of use.
Alignment Procedures	Shall	Alignment Procedures can only be performed by manufacturer.
Spectators	Shall	SOP contains authorization level and procedures for visitors.
Service Personnel	ULSO Determination	N/A. Only the manufacturer will perform service to the laser generating systems within the protective housings.
Laser Eye Protection	Shall	SOP requires eye protection & annual training addresses eye protection.

TABLE A-I. *Class 4 control measures per ANSI Z136.1* – Continued.

Control Measure	Class 4 Requirement	*CleanLASER* CL300 and CL1000 Compliance
Skin Protection	Should	SOP requires skin protection.
Protective Clothing	Should	SOP requires protective clothing and sunblock.
Laser Optical Fiber Transmission Systems	Shall	N/A. This is not an enclosed system.
Laser Robotic Automated Installations	Shall	N/A. This is a hand-held device that will be used by an operator.
Laser Controlled Area Warning Signs	Shall	SOP mandates the use of ANSI compliant signs and beacons.

APPENDIX B

SAMPLE STANDARD OPERATING PROCEDURES

B.1 SCOPE

B.1.1 Scope. This appendix provides an example set of standard operating procedures (SOP) to be tailored by the BEE/ILSO. This SOP is strictly an example to facilitate use of the 300W and 1000W HHLs and is not official until signed by the BEE/ILSO. The applicable DoD Service Agency protocol regarding coordination, documentation, and format will be followed.

Hand Held Laser (HHL)
Standard Operating Procedures (SOP)
For
XXXXXXXXXXXXX

Use with CL300 and CL1000 Lasers

DANGER

Failure of the operator or bystanders to wear appropriate eye protection can result in immediate permanent eye damage including blindness.

B.2 GENERAL INFORMATION

B.2.1 The CL300 and CL1000 handheld lasers are Class 4 lasers which permits human access during operation when levels of laser radiation may be harmful. The lasers operate at 300 and 1000 Watts average power, respectively, with a wavelength of 1064 nm (nanometers). Only qualified laser operators will operate the lasers. You will observe all operating guidelines included in this SOP and a copy will be maintained with the laser.

B.2.2 This SOP supplements the equipment owner's manuals, the local laser safety training courses, the shop Job Safety Training Outline, AFI 48-139, *Laser and Optical Radiation Protection Program*, or other Service equivalent. Users will be aware of applicable guidance in these and other publications.

B.2.3 The lasers and laser system chillers are mounted on a cart for mobile operation. The laser beams are delivered via fiber optical cable and a manually operated End effector. Each laser system utilizes a HEPA filtration system, which uses a vacuum system to remove the emissions and particulates at the laser head.

B.2.4 All maintenance and servicing of the laser system in the maintenance manuals will be performed by personnel who are properly trained/authorized to perform the task required. Changes to the beam or optic will only be performed by the Original Equipment Manufacturer (OEM) or their authorized distributor/repair contractors.

B.2.5 The ablation process: The lasers remove coatings (paint, primer) and corrosion via the ablation method. It is a mechanical process that uses pulsed lasers which create burst of high intensity energy. During the process a thin layer of material is vaporized and converted into plasma creating a shockwave that cracks the coating facilitating the removal of the remaining materials. Figure B-1 provides an illustration of the laser ablation mechanism.

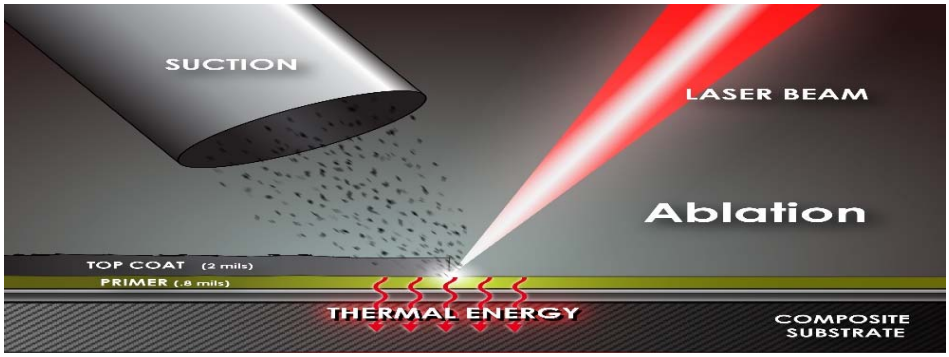

FIGURE B-1: *Laser Ablation Process*

B.3 SAFETY

B.3.1 Remove rings, watches and other jewelry from hands and arms.

B.3.2 The laser radiation is not visible; however, once the laser contacts a coating or corrosion, the reaction often produces visible light and/or an audible sound. The user will always keep in mind that when the trigger is pulled, invisible laser radiation is being released.

DANGER

Failure to wear appropriate eye protection can result in immediate permanent eye damage including blindness.

B.3.3 Beam hazards. The beam is invisible and has sufficient levels of laser radiation to cause temporary or permanent damage to the eyes, and skin damage. The laser controlled area will be set-up as described in this SOP.

B.3.3.1 Laser eye protection will be worn by all personnel within the controlled area during laser operation as described in this SOP.

B.3.4 Non-beam hazards. Several non-beam hazards exist; these hazards are listed below and mitigated by the design of the laser, local engineering controls, personal protective equipment (PPE), and procedural controls defined in this SOP.

B.3.4.1 Electrical hazards. Electrical hazards exist due to the high voltage used to operate and generate the laser. Only the OEM or qualified distributor will service or troubleshoot electrical components.

B.3.4.2 Heat. Heat generated when the laser ablates the surface may cause burns if touched. Infrared (IR) light may cause elevated heating of skin.

B.3.4.3 Optical radiation. Non-coherent ultraviolet (UV), white (bright visible ablation light) and IR light may be emitted from the plasma emissions created during laser use and may pose a long-term health hazard if PPE and/or sunblock are not worn.

B.3.4.4 Fire hazard. Fire hazard is minimal with the CL300 or CL1000 when used per this guidance and other required documentation. Remove flammable or combustible materials from the laser area that are not required and do not hold the laser stationary over flammable or combustible materials. When using laser safety curtains, use those provided by the distributor or those intended to withstand the power/frequency of the laser. The lasers can ignite combustibles

and some metals, such as magnesium. Specular and diffuse beams may contain sufficient energy to ignite nearby combustibles. Keep the HHL and the dust collection unit at least three feet away from spray booth openings when paint spraying operations are taking place.

B.3.4.5 Noise. Hearing protection may need to be worn when using this equipment; this is due to the combined noise levels in industrial areas (in isolation, this equipment is below action levels, but when it is combined with the noise generated by other nearby operations, thresholds are often exceeded and hearing protection is required).

B.3.4.6 Laser Generated Air Contaminants (LGAC). These contaminants can be in the form of particles and/or gasses. They are collected by the vacuum/filtration system. (Note: Do not use in small rooms with no ventilation). Combustion and/or decomposing products may produce toxic or noxious fumes and vapors.

B.3.4.7 Ergonomics. The HHL is comparable to other paint removal processes, such as sanding and blasting, maintain a comfortable position as often as possible. Air sampling testing performed by USAFSAM has shown the TEKA LFE 301 vacuum/filtration system is effective in capturing all contaminants and respirators are not required while operating the HHL.

B.4 ACCESS CONTROL

B.4.1 The key to the laser control panel will be maintained in the consolidated tool kit (CTK) and will only be provided to qualified operators or the cognizant engineers that are trained and have a valid requirement. The key will be returned upon completion of work and will never be left unattended to prevent unauthorized use.

B.4.2 Visitors. Visitors/spectators will be approved by a supervisor. Qualified operators will provide visitors with a safety briefing and required PPE. Visitors will be briefed on safe work practices, specific hazards, and procedures to follow in the event of a suspected overexposure to laser or other optical radiation (symptoms include headache, sudden appearance of floaters in their vision, watery eyes, eye pain, pressure or “popping”, blindness), as well as the location of emergency stops.

B.4.2.1 A qualified laser operator will inspect the laser eye protection before the visitor dons the glasses/goggles. Visitors will wear laser eye protection at all times when inside the controlled area and the laser is powered on.

B.4.2.2 Visitors will be instructed to wash their hands prior to eating or drinking.

B.5 OPERATOR SELECTION

B.5.1 Selection. Select people with sound decision making skills and that can be relied upon to follow the SOP and control procedures to ensure safe laser use.

B.5.2 Eye Exam. Users, including trainees, will receive a pre-placement eye exam/optical screening.

B.6 TRAINING

B.6.1 All employees will accomplish annual laser safety training; for new employees, this will be accomplished prior to using the laser.

B.7 AUTHORIZED USE

WARNING

Use of the lasers on unapproved materials, such as plastics, can result in unknown emissions which could pose health concerns.

B.7.1 The lasers are currently authorized for use on the metal substrates of Aerospace Ground Equipment (AGE). It may also be used for cleaning paint/corrosion on metal hand tools.

B.7.2 Do not use on aircraft or aircraft parts without prior approval. To request approval for other applications contact the cognizant engineering authority.

B.7.3 Do not use the lasers outdoors without prior approval as this SOP does not authorize outdoor use. Contact the installation laser safety officer and flight safety in advance with sufficient time to gain approval.

B.8 MAXIMUM PERMISSIBLE EXPOSURE (MPE) and NOMINAL HAZARD ZONE (NHZ)

B.8.1 MPE is the level of laser exposure to which the eye or (less limiting) the skin, may be exposed without adverse effects. NHZ is the space within which the level of direct, reflected or scattered radiation during operation exceeds the applicable MPE. See Table B-I below:

TABLE B-I. *NOHD and NSHD for CL300 and CL1000*

	Laser NOHD (safe distance for eyes when viewing direct beam or specular reflection)	**Laser NSHD (Safe distance for skin for direct beam)**
CL300	105 feet (32 meters)	6 feet (2 meters)
CL1000	174 feet (53 meters)	13 feet (4 meters)

NOHD = Nominal Ocular Hazard Distance
NSHD = Nominal Skin Hazard Distance

B.8.2 The NHZ is dependent on several factors which the user cannot modify. If the optics are replaced by the OEM or qualified distributor, and if altered, new NHZ calculations will be performed by the installation laser safety officer (ILSO) and/or USAFSAM before use.

B.8.3 Enclosed room. When used in an enclosed room where there's no opportunity for the laser beam to escape, the NHZ is the space inside the closed room.

B.8.4 Shielded environment. When used with curtains and other barriers such as walls, the NHZ is the space within the curtains/walls and the space above the curtains extending past the curtains a distance equal to the Nominal Ocular Hazard Distance (NOHD). See Table B-I.

B.8.5 When the laser is powered on, everyone within the laser controlled area will don laser eye protection before the end effector is picked up by a user.

B.8.6 Users will always exercise caution and evaluate how they are using the laser, especially when working near the surface edges. In order to strip paint or corrosion to the edge of the metal substrate, a portion of the laser beam may overrun the edge. Users will be aware of what/who is in the distance.

B.9 PRIOR TO USE PROCEDURES (See Appendix C)

B.9.1 NHZ area setup requirements.

B.9.1.1 Laser safety signs. Posted at the entryway to the laser controlled area. See Figure B-2.

FIGURE B-2: *Laser Safety Sign Example*

B.9.1.2 Laser safety beacon will be positioned next to each sign and activated so it is visible by people approaching before they enter the laser controlled area. See Figure B-3.

FIGURE B-3. *Laser Safety Beacon*

B.9.1.3 Enclosed room procedures.

B.9.1.3.1 Visually inspect the exterior of the room to ensure there are no areas (windows, gaps, or similar area) where the direct laser beam can escape and injure someone.

B.9.1.3.2 Visually inspect the door safety interlock switches.

B.9.1.3.2.1 Connect the interlock connector to the port on the laser system.

B.9.1.3.2.2 Ensure windows are completely covered with opaque materials or are a laser safety window meeting the requirements for 1064nm OD6+ Nd:YAG, which will be intact (no scratches, pitting, cracks, or similar type damages).

B.9.1.3.2.3 Any combustible items will be removed or covered with laser safety curtains.

B.9.1.4 Shielded environment:

B.9.1.4.1 Curtains will be placed to prevent the direct laser beam from going beyond the curtains and will be free of gaps.

B.9.1.4.2 The laser controlled area will be contained 360^{o} around the work area, both horizontally and vertically, to the extent of the NOHDs.

B.9.1.4.3 Verify that no workers or visitors are or will be in the overhead areas within the NHZ (105 feet for CL300 and 171 feet for CL1000) where eye exposure with the direct laser beam may cause damage.

B.9.2 Prior to laser operation.

B.9.2.1 Masking.

B.9.2.1.1 Areas that need to be protected or are not going to be lased will be masked with the following material: aluminum foil NSN 9535-00-684-4668 for .001 thick, NSN 9535-00-242-5665 for .003 thick or equivalent; and aluminum tape.

B.9.2.1.2 Items to mask: non-metallic parts, plastic (including gas caps), electrical connectors, bearings, rod ends, rubber, wiring, openings with access to interior components.

B.9.2.2 Items to check.

B.9.2.2.1 Supplied maintenance logs.

B.9.2.2.2 Protective glass for dirt and clean if necessary.

B.9.2.2.3 Protective hose for damage or loose connections.

B.9.2.2.4 Protective housings on the laser are closed and interlock switches are not bypassed.

B.9.2.3 PPE:

WARNING

Failure to wear appropriate eye protection can result in immediate permanent eye damage including blindness.

B.9.2.3.1 Inspect then don Laser Eye Protection (LEP) and ensure a good fit.

B.9.2.3.1.1 If more than one type of laser is operated in the facility, ensure the correct LEP are being used. Both the 300W and 1000W laser unit require LEP compatible with 1064nm OD6+ Nd:YAG.

B.9.2.3.1.2 Light leaks. Ensure the LEP does not have light leaks such as separation between the frame and lenses

B.9.2.3.1.3 Lens condition. Check the lenses for scratches, pitting, surface cracks, or discoloration. All of these defects may reduce the filtering ability of the LEP. If the device has been subject to extreme environmental stresses, consider replacement or testing of the lens.

B.9.3 Start the unit per the OEM's manual.

B.9.4 Prior to use check the following:

B.9.4.1 Distance/movement sensor stops the laser beam if too far out of focus or no movement.

B.9.4.2 Ensure the vacuum system is providing suction at the nozzle.

B.9.5 Cease use immediately if any of the following conditions are present:

B.9.5.1 Personnel enter the NHZ without LEP.

B.9.5.2 Damage to protective hose.

B.9.5.3 The laser is not functioning properly.

B.9.5.4 The vacuum system stops operating.

B.9.5.5 Flammable vapors are present.

WARNING

Do not use when flammable vapors are present. The laser system has standard electrical wiring; it is not rated for use in hazardous areas.

B.9.6 During use, ensure:

B.9.6.1 Laser is never directed at humans, animals or other unauthorized area.

B.9.6.2 The laser beam is not at eye level for persons standing or sitting in hazard areas.

B.9.6.3 Do not subject the protective hose to any mechanical forces (tension, pressure, torsion, bending, crushing, or rolling over with equipment with casters). The maximum pull/push force on the cable is 22 lbs. The bend radii for the protective hose are: 10” radius for the CL300 laser; 12.5” radius for the CL1000 laser.

B.9.6.4 All doors, windows, and openings will remain covered or restricted to prevent transmission of the laser beam or unauthorized access.

Caution

Operating the laser with residual condensation on optical elements can lead to heavy damage and major repairs.

B.9.6.5 If transported, avoid extreme changes in humidity and /or temperature. Allow unit time to acclimate before operating. Residual condensation on optical elements can lead to heavy damage and major repairs.

B.9.6.6 The angle of the end effector is not kept at 90 degrees (perpendicular to the surfaced being lased) for prolonged periods; it should be 10-15 degrees off from perpendicular.

B.10 UPON COMPLETION OF USE

B.10.1 Shut the unit down per the OEM's manual.

B.10.2 Remove the key and return it to the CTK.

B.10.3 Deactivate the external beacon.

B.11 DURING MAINTENANCE

B.11.1 Ensure the key is turned off and removed for maintenance activities that do not require power.

B.11.2 Disconnect all power cords and air hoses from their receptacles.

B.11.3 Verify warning labels are intact; replace those that are missing or no longer readable.

B.11.4 Users will *only* perform user level maintenance per the OEM's manuals. All maintenance actions to the laser generating equipment are performed by the OEM or qualified distributor.

B.11.5 When conducting maintenance actions on the filtration system, workers will wear standard PPE for handling chromated dusts.

B.12 ACCIDENT/INCIDENT

B.12.1 In the event of a suspected laser accident/incident, seek immediate medical treatment.

B.12.2 If Service members are injured, they will notify their chain of command and ILSO (usually the Bioenvironmental Flight Chief in the Medical Group).

APPENDIX C

PRE-USE, STARTUP, AND SHUTDOWN PROCEDURES

C.1 SCOPE

C.1.1 Scope. This Appendix contains a checklist that is for use with the 300W and 1000W HHL's. These checklists will be used, unless the BEE/ILSO supersede them, prior to use, and during shutdown of the 300W and 1000W HHL's.

	Perform Pre-use Procedures for Lasing	
1	Ensure laser safety signs posted and beacons visible from all sides	Yes/No
2	Personnel in the hazard zone briefed on hazards - Remove rings, watches and other jewelry from hands and arms - Apply sunblock with an SPF of 30 or higher to exposed skin areas or long-sleeve garment - Don gloves: leather, pig-skin, deerskin, nitrile, nomex flight glove, or equivalent glove - Ensure wrists are not exposed – prolonged exposure may negate the use of sunblock	Yes/No
3	Ensure anyone that enters the site and may be in an elevated position (i.e. civil engineering) is briefed on the hazards and provided PPE as needed	Yes/No
4	Personnel in the hazard zone wearing approved: - Laser Eye Protection (OD6+ at 1064nm) Goggles with 1000W laser	Yes/No
5	Ensure the laser controlled area is contained – 360^{o} in all directions	Yes/No
6	All protective covers on the laser are closed	Yes/No
7	Check Maintenance Forms	Yes/No
8	Visually inspect the door safety interlock switches and connect to the port on the laser or connect jumper (if applicable)	Yes/No
9	Enclosed room: Examine the exterior - ensure no areas where the direct laser bean can leak (if applicable)	Yes/No
10	Curtains: placed to prevent direct laser beam leaking – no gaps (if applicable)	Yes/No
11	Any window will be completely covered: laser curtains/sheet metal/aluminum foil, etc. Rated the same as the safety glasses (if applicable)	Yes/No
12	Clear area of combustible/flammable material (solvents, paper, cardboard, paint filters etc.)	Yes/No
13	Cover any interior areas that are combustible with safety curtains and/or laser masking material	Yes/No

	Preparation for Lasing	
1	Authorized items only! - Metal AGE parts/hand tools are authorized. Do not lase aircraft parts/components without specific authorization to do so.	Yes/No
2	Remove heavy combustible materials from item to be lased - Oil, grease, chemicals, etc.	Yes/No
3	Prepare item(s) to be lased - Remove decals, water, solvents, etc.	Yes/No
4	Mask off non-metallic parts (plastic, rubber, wiring, etc.) and openings to prevent damage: Aluminum foil (NSNs 9535-00-684-4668 for .001" and 9535-00-242-5665 for .003") Aluminum tape	Yes/No
5	Inspect then don Laser Eye Protection (LEP) for damage and ensure a good fit	Yes/No

	Pre-Use Inspection	
1	Inspect laser system (damage/wear/leaks, etc.)	Yes/No
2	Connect compressed air lines	Yes/No
3	Inspect the end effector protective glass – Clean/replace if needed	Yes/No
4	Inspect the end effector nozzle for particulates Clean if dirty	Yes/No
5	Ensure protective housings on the laser are closed and interlock switches are not bypassed	Yes/No
6	Emergency stop button - in the up (released) position	Yes/No
7	Connect electrical plug on filtration system & connect compressed air line	Yes/No
8	Inspect vacuum hose on filtration system for damage, replace if needed	Yes/No
9	Manually activate the external beacons located at the entryways to the controlled area to indicate the laser is being used and hazardous laser light may be present.	Yes/No

	System and Filtration Start Up	
1	Insert the key into the laser and turn clockwise to "ON" position. Wait for "*The laser is now ready for operation*".	Yes/No
2	Check display screen – error/warning messages – Resolve, if necessary.	Yes/No
3	Power up filtration system - press and hold power button until the system turns on.	Yes/No
4	Check the screen for any warnings and address.	Yes/No
5	Connect to the end effector - Verify suction at end effector nozzle.	Yes/No

	System Operation and Shutdown	
1	Ensure everyone is wearing the correct laser eye protection	Yes/No
2	Choose the proper power level for the CL1000 or CL300 (1000W or 300W button on touchscreen display)	Yes/No
3	Select appropriate operating settings – pulse frequency/scan frequency/scan speed/scan width	Yes/No
4	Keep the laser in focus and moving (Sensor package will stop laser operation, CL300 only)	Yes/No
5	Inspect the end effector protective glass – Clean/replace if needed	Yes/No
6	Turn key counterclockwise to the OFF position	Yes/No
7	Unplug/store protective hose and power cords; Do not kink or bend the protective hose.	Yes/No
8	Check protective glass and nozzle for dirt/deposits.	Yes/No

	Filtration system shutdown	
1	Hold down power button until unit shuts off (it will run for 5 Minutes following laser shut-down) – powered with laser in some systems	Yes/No
2	After system completes the automated shutdown procedure, unplug electrical cord. Store protective hose and power cords - Do not kink or bend the protective hose	Yes/No
3	Turn off or disconnect air supply if necessary	Yes/No

Concluding Material

Custodian:

Navy – AS

Air Force - 184

Preparing Activity:

Air Force – 184

(Project MFFP-2019-003)

Reviewer:

Army - CR

Navy - SH

Air Force – 11, 19, 20, 70

Agent:

Air Force - 99

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.dla.mil.