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Pulsed Laser Ablation Technical Guide for Ferrous Metal Substrates

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Foreword

This guide is intended to assist surface preparation specifiers and end users in determining the suitability and benefits of Pulsed Laser Ablation (PLA) coating removal/cleaning, Laser Ablation Coating Removal (LACR) hereafter all referred to as PLA, using Q-switch technology for industrial applications on ferrous metal substrates. It describes the technology, capabilities, and limitations of commercially available laser systems specifically designed to remove coatings, rust, grease/oil, and contaminants, safely and effectively, in a process that uses only high-intensity focused light.

PLA should be used for general corrosion mitigation and surface preparation before recoating. PLA can remove 100% of existing coatings. However, it is most effective for applications requiring less than 95% coating removal (by the surface area of the exposed substrate). The primary functions of PLA cleaning before coating applications are:

a) To remove material from the surface that can cause premature failure of the new coating system
b) To enhance the adhesion of a new coating system
c) To expose the surface profile of the substrate that is underneath the existing coating, or rust and other corrosion products (Appendix A provides additional information); and,
d) To reduce or remove nonvisible contamination that may be present on the substrate. Examples include thin films of oil and grease, and soluble ionic materials such as chlorides, ferrous salts, nitrates, and sulfates. PLA can reduce or completely remove water-soluble contaminants as well as fixed, non-smearable low-level radiological contamination.

AMPP SP21511-1, "Laser Ablation for Surface Preparation of Ferrous Metals, Pulsed Laser" is a standard that is strongly recommended for use for PLA, and reference is made to it from this guide.

Rationale

Commercially available PLA systems offer a new solution for a wide range of industrial surface preparation applications. However, when considering the potential use of this technology, a need exists for technical reference materials that will educate surface preparation professionals and enable informed decision-making to determine when, why, and how to use PLA as the best value option. This guide is intended to address that need, and in doing so, support the use of AMPP SP21511-1.

Referenced Standards and Other Consensus Documents

Unless specifically dated, the latest edition, revision, or amendment of the documents listed in the table below shall apply.

AMPP/NACE/SSPC, www.ampp.org:	
AMPP SP21511-1	Laser Ablation for Surface Preparation of Ferrous Metals, Pulsed Laser
NACE SP0169	Control of External Corrosion on Underground or Submerged Metallic Piping Systems
NACE SP0178	Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service
SSPC-Guide 12	Guide for Illumination of Industrial Coating Projects
SSPC-PA 17	Procedure for Determining Conformance to Steel Profile/Surface Roughness/Peak Count Requirements
SSPC-SP COM	Surface Preparation Commentary
SSPC-SP 1	Solvent Cleaning
SSPC-SP 6/NACE No. 3	Commercial Blast Cleaning
SSPC-SP 7/NACE No. 4	Brush-Off Blast Cleaning
SSPC-SP 10/NACE No. 2	Near-White Metal Blast Cleaning
SSPC-SP 17	Thorough Abrasive Blast Cleaning of Non-Ferrous Metals
SSPC-SP 18	Thorough Spot and Sweep
SSPC-VIS 1	Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning

ASTM International, www.astm.org:	
ASTM A131	Standard Specification for Structural Steel Plates
ASTM/IEEE SI10	American National Standard for Metric Practice
ASTM D16	Standard Terminology for Paint, Related Coatings, Materials, and Applications
ASTM D522	Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings
ASTM D3359	Standard Test Methods for Rating Adhesion by Tape Test
ASTM D4285	Standard Test Method for Indicating Oil or Water in Compressed Air
ASTM D4414	Standard Practice for Measurement of Wet Film Thickness by Notch Gages
ASTM D4417	Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel
ASTM D4541	Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
ASTM D6677	Standard Test Method for Evaluating Adhesion by Knife
ASTM D1141	Standard Practice for Preparation of Substitute Ocean Water
ASTM E8	Standard Test Methods for Tension Testing of Metallic Materials
ASTM E466	Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
ASTM G8	Standard Test Methods for Cathodic Disbonding of Pipeline Coatings
ASTM G39	Standard Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens
ASTM G44	Standard Practice for Exposure of Metals and Alloys by Alternate Immersion in Neutral 3.5 % Sodium Chloride Solution

American Welding Society (AWS), www.aws.org:	
AWS B4.0	Standard Methods for Mechanical Testing of Welds

American National Standards Institute (ANSI), www.ansi.org:	
ANSI Z136.1	Safe Use of Lasers
ANSI Z136.6	Safe Use of Lasers Outdoors

Deutsches Institut für Normung (DIN), www.din.de/en:	
DIN 12254	Screens for Laser Working Places – Safety Requirements and Testing

International Organization for Standardization (ISO), www.iso.org:	
ISO 8502-3	Preparation of steel substrates before application of paints and related products—Tests for the assessment of surface cleanliness – Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)

International Electrotechnical Commission (IEC) www.iec.ch:	
IEC 60825-1	Safety of Laser Products, Part 1: Equipment Classification, and Requirements

National Fire Protection Association (NFPA), www.npfa.org:	
NFPA 115	Standard for Laser Fire Protection

This guide provides both U.S. customary units and IEEE/ASTM SI 10, "American National Standard for Metric Practice" International System (SI) units. The measurements are not exact equivalents; therefore, each system must be used independently of the other, without combining in any way. This guide uses SI units and provides U.S. customary units shown in parentheses for information only.

Section 1: Scope

This guide describes the use of portable or stationary Q-switched pulsed laser ablation (PLA) systems, consisting of directed energy technology for the surface preparation of ferrous substrates as required for applying coatings or linings, welding, adhesive bonding, decontamination, and other applications. It will discuss the feasibility and benefits of PLA when compared to other laser technologies as well as traditional surface preparation methods. Detailed information is provided on the equipment, including a generic description, suitable applications and locations for use, types of coatings or contaminants suitable for removal, advantages, and limitations. This guide includes requirements for operating conditions, and environmental, health, and safety compliance. Appendix A provides explanatory information, some of which uses terms specific to AMPP SP21511-1, "Laser Ablation for Metallic Surface Preparation of Ferrous Metals, Pulsed Laser." Appendix B provides an amplification of considerations for use including technical information regarding the interaction of the laser with coatings and substrate. Appendix C addresses additional considerations for environmental approvals. Appendix D lists equipment and operating parameters. A visual guide, proposed nomenclature AMPP Guide 21711, titled "Guide and Reference Photographs for Steel Surface Non-Mechanical Cleaning by Pulsed Laser Ablation" is in development.

This guide applies only to the use of Q-switched PLA systems on ferrous metal substrates (does not include stainless steel) and the coatings applied to them. There are numerous laser types and substrate materials that may be suitable for certain laser treatments. Other laser types and substrates will be addressed by separate standards in the future.

Continuous wave laser technology, also called CW lasers, designed to remove target materials by combustion, versus ablation/vaporization, is not within the scope of this guide.

Section 2: Definitions

For the purposes of this guide, the following terms and definitions apply:

Ablation Cleaning (AC): Application of PLA to prepare a surface for follow-on surface treatments, cosmetic improvements, or decontamination. Typically used for removal of surface contaminants and surface rust from bare substrates or other coated surfaces requiring cleaning similar to SSPC-SP 1, Solvent Cleaning.

Class 4 Laser: The most dangerous and highest laser classification, of classifications ranging from 1 to 4. Depending on the wavelength, at a power output above 500 milliwatts, beam exposure can result in severe eye injury from both direct and scattered beam reflections and may be harmful at large distances from the laser source. Class 4 lasers can injure the skin, cause thermal burns, present a significant fire hazard, and when used for ablation, these lasers create airborne contaminants that can be hazardous. The use of Class 4 lasers must comply with regulatory safety requirements, which vary according to where and how the laser is used.

End Effector: A hand-held manually operated device the laser operator uses to turn the laser beam on and off while focusing direct laser energy onto the work surface. Laser end effectors include designs for automated remote-controlled operation. See also *Laser Optic* below.

Focal Range: The plus or minus distance from the target surface within which effective laser ablation will occur using a focused laser beam with a specific focal length. The actual focal range for a particular PLA system is determined by the specified focal length of the laser end effector's aperture lens and the power output of the laser system. Typically, the focal range increases relative to higher laser power.

Laser (acronym for Light Amplification by Stimulated Emission of Radiation): For the purposes of this document, the laser is a device that stores and releases pulsed, high-intensity focused light very rapidly so that the laser output can