

# **Process Specification for Laser Marking & Laser Engraving**

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**Engineering Directorate**

**Structural Engineering Division**

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# Process Specification for Laser Marking & Laser Engraving

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REVISIONS		
VERSION	CHANGES	DATE
--	Original version	March 3, 1996
A	Reformatted to new PRC format, updated paragraph. 2.0	July 27, 1999
B	Updated list of materials that can be laser engraved under section 2.0; added paragraph to section 2.0 specifying that laser engraving of titanium alloys in air is not recommended; deleted all references to Universal Laser Systems Inc. Model ULS-25 engraving system; replaced <i>EM-007.1</i> with <i>SOP-007.1</i> , added paragraph to section 8.0d specifying to perform a metallurgical inspection/evaluation of laser engraved coupon to confirm established system parameters are acceptable for a given part; replaced <i>EM2</i> with <i>ES4</i> where applicable.	03/09/2012
C	Updated sample process notes to call out laser marking/laser engraving under section 3.0 USAGE; modified subsections under 3.0 USAGE; added AMS- H-6875 and JSCM 5312 to section 4.0 REFERENCES; added Table 1, <i>Approved Materials for Filled Impressions</i> to section 5.0 TOOLS, EQUIPMENT, and MATERIALS REQUIREMENTS; modified section 6.0 PROCESS REQUIREMENTS; modified section 7.0 PROCESS QUALIFICATION, modified subsection 7.1 PROCESS QUALIFICATION DOCUMENTATION; modified section 8.0 PROCESS VERIFICATION	10/26/2012
D	Updated revision, date, and <i>Approved by</i> signature; added reviewed by signature; updated Section 2.0 <b>APPLICABILITY</b> ; noted chemical conversion coating shall not be used as corrosion protection on filled engraved impressions in Section 2.0; added statements to Section 3.0 <b>USAGE</b> stating when to laser mark and when to laser engrave and referenced Section 10.0 on process distinctions; deleted additional marking requirements for Space Station Payloads per SSP 57000, Appendix C under Section 3.0; added statements to Section 3.0 recommending to laser engrave/mark in low stress locations so as to prevent cracking and fatigue; moved steel restrictions to Section 3.2 <b>RESTRICTIONS</b> ; reworded factors to consider when selecting laser marking/engraving location in Section 3.4 <b>CHARACTER LOCATION AND LIGIBILITY</b> ; updated Section 10.0 <b>Definitions</b> ; minor grammatical corrections.	06/2020

Verify correct version before use.

## 1.0 SCOPE

This process specification establishes the requirements for laser marking and laser engraving of flight and non-flight hardware manufactured by JSC or outside vendors.

## 2.0 APPLICABILITY

This process specification applies to laser marking and laser engraving on the surface of materials such as wood, acrylic, engraver's plastic, glass, leather, stone, rubber, some steels, cobalt-based alloys, aluminum, titanium, and copper-based alloys (except C17200).

Coated metals may be laser marked/engraved using this procedure. The process can completely remove the coating, but it shall not significantly compromise the base material. Before using this process, it shall be verified with NASA-JSC/M&P that complete removal of the coating will not adversely affect the performance of the base material. Chemical conversion coatings shall not be used for corrosion protection on laser engraved aluminum alloys as when for instance laser engraving penetrates past the anodic coating. Engraved impression shall be filled with primer instead, and color paint if desired.

## 3.0 USAGE

This section gives the requirements for the proper design usage of this process specification.

Laser marking is generally used for identification purposes, when assigning a part number (P/N) and/or serial number (S/N) to component parts. Laser engraving is generally used for indication purposes on tools, when filling engraved impression with color paint for example. Section 10.0 provides a distinction between laser marking and laser engraving.

Laser marking and/or laser engraving shall be invoked by a process note on the engineering drawing. The process note shall reference this PRC. Character height and depth (when applicable) shall follow, along with any additional requirements. In addition, the process note shall specify the location of the characters. The following are example process notes:

**LASER ENGRAVE PART with {words, numbers, arrows, alignment marks, etc.} PER NASA/JSC PRC-9003. CHARACTER HEIGHT SHALL BE 3/16 INCH. CHARACTER DEPTH SHALL BE 0.003 INCH. LOCATE APPROXIMATELY AS SHOWN.**

**LASER MARK PART with {words, numbers, arrows, alignment marks, etc.} PER NASA/JSC PRC-9003. CHARACTER HEIGHT SHALL BE 3/16 INCH. LOCATE APPROXIMATELY AS SHOWN.**

Laser marking/engraving shall be performed on low stress locations within a part, where fatigue propagation is not expected to occur.

Work-hardened alloys can be adversely effected by laser marking/engraving. Changes in the residual stress at the surface after laser processing can make the surface more prone to fatigue or stress corrosion cracking.

Gears should be marked in low-stress locations away from carburized regions. Lasers not only produce cracks in carburized (and nitrided) surfaces from untempered martensite, but also create burn (decarburization).

Laser mark/engrave away from high stress locations like fillets, part edges and bolt holes.

### **3.1 BASE MATERIALS**

The minimum base material thickness for all metallic, molded, or sheet plastic materials to be laser marked/laser engraved shall be 0.030 inch. The minimum base material thickness for multi-layer or reinforced laminates shall be 0.060 inch.

### **3.2 RESTRICTIONS**

Laser marking/engraving of parts shall not be performed on the following items without prior NASA-JSC/M&P approval:

- a. Ferrous parts heat-treated above 160 ksi ultimate tensile strength (UTS) and metallic parts work-hardened above one-fourth harder than the normal annealed condition.
- b. Surfaces contoured to a dimension
- c. Areas where subsequent metal removal will obliterate the marking/engraving
- d. Less than 1/4 inch from weld beads
- e. Metal tank skins
- f. Pressure tubing and push-pull control tubing
- g. Pressure vessels

There are specific restrictions on the classes of steels that can be laser marked/engraved.

AMS-H-6875 classifies steels into four classes:

- Class A (carbon and low alloy steels) – i.e.: 4140, 4340, 52100, carburized 9310
- Class B (martensitic corrosion-resistant) – i.e.: 410, 416, 420, 440C
- Class C (austenitic corrosion-resistant) – i.e.: 302, 304, 304L, 316, 316L
- Class D (precipitation hardening) – i.e.: 15-5PH, 17-4PH, Custom 455, Custom 465

Class A, Class B, and some Class D steels shall not be laser marked/engraved.

- High levels of untempered martensite may form after laser marking/engraving on Class A and B steels.
- Cracks and brittle, untempered martensite are produced on Class D steels such as Custom 455 and Custom 465 as a result of the laser marking/engraving process.

Laser marking/laser engraving may be performed on Class C (i.e.: 302, 304, 304L, 316, 316L) steels. Prior M&P approval is required to laser mark/engrave Class C steels work-hardened above one-quarter hard as noted in section 3.2a.

Some class D (i.e.: 15-5PH and 17-4PH) steels may be laser marked/engraved. Prior M&P approval is required to laser mark/engrave Class D steels.

### 3.3 CHARACTER SIZE

Character size shall be specified on the engineering drawing. The choice of character height shall be in increments of 1/32 inch, from 1/16 to 1/2 inch inclusive. Character size in accordance with the point value system is acceptable, with 12-point being preferred. The size of characters shall be proportioned to the area available for laser marking/laser engraving. The size of characters shall be uniform from part to part within the practical limits of readability. An example of the character size callout is as follows:

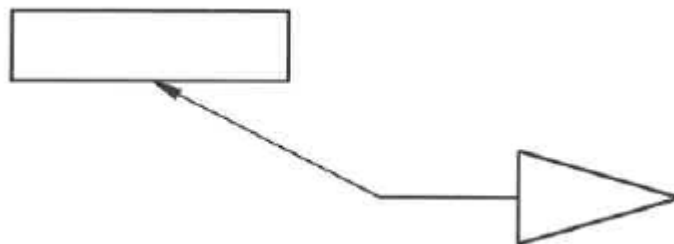
#### **CHARACTER HEIGHT SHALL BE 3/16 INCH.**

Characters shall be marked/engraved to a depth necessary to obtain the required width for legibility. The depth of the character shall be 0.003 minimum, and shall not exceed 50 percent of the base material thickness.

#### **CHARACTER DEPTH SHALL BE 0.003 INCH.**

### 3.4 CHARACTER LOCATION AND LEGIBILITY

The location of the characters shall be specified on the engineering drawing. The character location shall be indicated on the drawing with a flagged box. The general configuration for a flag note to specify the character location is shown in Figure 1:



**Figure 1: Flag note configuration sketch designating character location.**

Specific information on the laser marking/laser engraving format for part and serial numbers, and how to write the flag note to indicate laser marking/laser engraving

placement may be found in Section 3.5. Factors that shall be considered when specifying a marking/engraving location include:

- ◆ damage to a critical surface due to laser marking/engraving.
- ◆ part number visibility at next assembly, top assembly, or installation level.
- ◆ obliteration of laser marking/engraving during assembly process
- ◆ legibility of component part numbers during verification process.

Assembly laser markings or laser engravings shall be legible under conditions of normal vision in daylight, or in equivalent illumination.

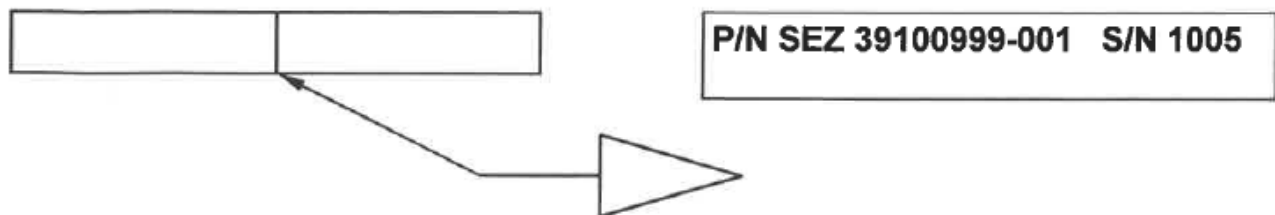
### 3.5 FORMAT FOR PART AND SERIAL NUMBERS

Each part or assembly shall be identified, except those parts which are permanently attached to other parts or assemblies (i.e. welding, brazing, or soldering). Parts which do not require identification may be marked/engraved for production convenience, provided the marking/engraving conform to the requirements of this specification. Any item marked/engraved per this specification shall include, as a minimum, the complete part number as shown in Figure 2.



**Figure 2: Example of identification marking/engraving consisting of a complete part number.**

Additional information to be included in the marking/engraving, such as the serial number, may be indicated on the engineering drawing in the drawing flag note. The information may be located below the part number or adjacent to it. Figure 3 shows an example of how to specifically indicate that the information shall be placed adjacent to the part number.



**Figure 3: Example of symbol to be used if information is to be located adjacent to the part number.**

Figure 4 shows an example of how to mark/engrave the additional information below the part number.

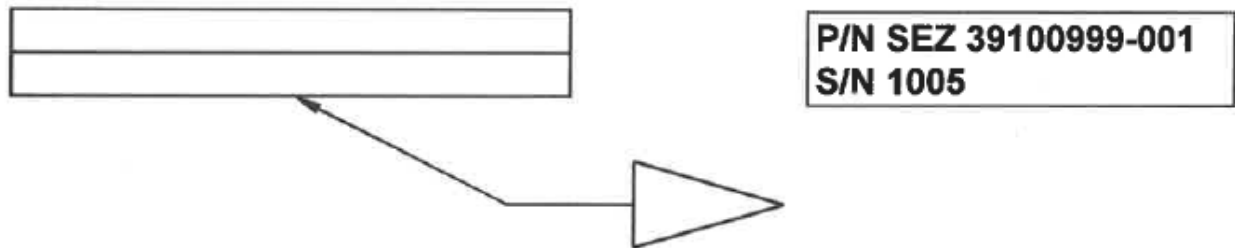


Figure 4: Example of symbol to be used if information is to be located beneath the part number.

### 3.5.1 Serial Numbers

Batch or lot controlled parts do not require serial numbers if a mandatory traceable batch lot system is used. All other parts or assemblies shall have serial numbers as specified in JPR 8500.4. A general example of the marking format for part and serial numbers is indicated in Figures 3 and 4.

### 3.5.2 Assemblies

Assemblies not identified with a nameplate that includes nomenclature of the part shall have the word “assembly” or “assy” placed immediately below the part number and serial number, as shown in Figure 5.



Figure 5: Example of identification markings/engravings on hardware that is part of an assembly.

### 3.5.3 Equipment

Equipment (i.e., valves, pumps, etc.) shall be marked/engraved with the following minimum information, in the order noted: Nomenclature, Part Number, Serial Number, Contract Number, Manufacturer, NASA-JSC.

### 3.5.4 Explosive Devices

Explosive devices shall be marked/engraved with the following minimum information: Nomenclature, Contractor, Manufacturer, Part Number, Lot Number, Serial Number, Date of Manufacture, ICC Classification.

### 3.5.5 Non-Flight Hardware

Hardware or equipment which is not suitable for use in flight and which could be accidentally substituted for flight articles shall be marked/engraved as either “Class III Not For Flight” or “Class II Controlled Equipment,” as shown in Figure 6.



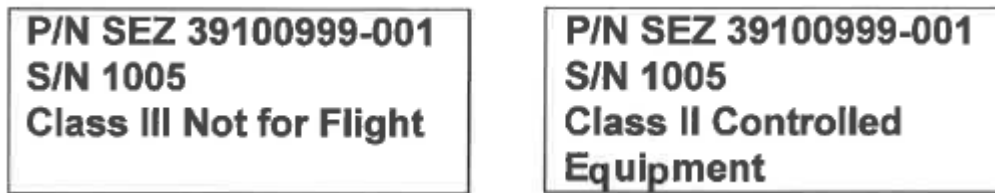


Figure 6: .Examples of the two options for laser marking/engraving non-flight hardware described in Section 3.5.5.

### 3.5.6 Rejected Flight Hardware

Hardware or equipment too small to be so marked/engraved shall be tagged with an appropriate red tag which is conspicuously identified: “Class II Controlled Equipment” or “Class III Not For Flight” per JSCM 5312 as shown in Figure 6.

### 3.6 FILLED IMPRESSIONS

If desired, marking/engraving impressions can be filled with a permanent coating in a contrasting color. The preferred color for filled impressions shall be black or white for maximum contrast. Filled impressions of other colors having contrast to the part are also acceptable. The product name and color of the coating used to fill impressions shall be specified on the engineering drawing in the parts list. Table 1 lists acceptable primer and coating products.

Filled impressions are specified by addition of one of the following process notes, depending on whether or not primer is required:

**IMPRESSIONS SHALL BE FILLED WITH {material}**

or

**PRIME WITH {primer} AND FILL IMPRESSIONS WITH {material}**

Primer must be used for filled flight hardware engravings, but is not necessary for ground support hardware. Both the primer and the filling material shall be added to the drawing parts list. Additional details regarding materials requirements for filled engravings are given in Section 6.4.1.

### 4.0 REFERENCES

The following references were used to develop this process specification:

- |            |  |
|------------|--|
| SOP-007.1  | Preparation and Revision of Process Specifications |
| JPR 8500.4 | Engineering Drawing System Manual                  |
| AMS-H-6875 | Heat Treatment of Steel Raw Materials              |
|            | Verify correct version before use.                 |

**5.0 MATERIALS REQUIREMENTS**

Specific tools and equipment shall be documented in the written work instructions for implementing this process specification.

Materials other than those listed in Table 1 shall be approved by the cognizant M&P engineering organization prior to use for filled impressions on flight hardware. All materials used for filled impressions shall be included on the engineering drawing.

**Table 1: Approved Materials for Filled Impressions**

Lord Corporation	Aeroglaze A276 (white/gloss polyurethane)	Filled Impressions
Lord Corporation	Chemglaze A382 (black/gloss polyurethane)	Filled Impressions
Lord Corporation	Chemglaze A074 (clear polyurethane)	Filled Impressions
Lord Corporation	Chemglaze 9986 (Catalyst)	Filled Impressions
Lord Corporation	Chemglaze 9958 (Thinner)	Filled Impressions
Preservo Paint & Coatings	Preservo 11105 (red polythane) <i>CP-500 Series</i>	Filled Impressions
Preservo Paint & Coatings	Preservo 15187 (blue polythane) <i>CP-500 Series</i>	Filled Impressions
Preservo Paint & Coatings	Preservo 13655 (yellow polyurethane) <i>CP-500 Series</i>	Filled Impressions
Preservo Paint & Coatings	Preservo 14260 (green polythane) <i>CP-500 Series</i>	Filled Impressions
Courtaulds Aerospace	Super Koropon 515-700 (Epoxy Base)	Filled Impressions
Courtaulds Aerospace	Super Koropon 910-704 (Epoxy Catalyst)	Filled Impressions
Nusil Technologies	CV-1144-1 or CV3-1144-1 (white RTV) with SP-120 silicone primer	Filled Impressions

## 6.0 **PROCESS REQUIREMENTS**

### 6.1 **WORK INSTRUCTIONS**

Work instructions shall be generated for implementing this process specification. The work instructions shall contain sufficient detail to ensure that the laser marking/laser engraving process produces consistent, repeatable products that comply with this specification. Work instructions shall contain adequate safety precautions and warning notes to ensure user safety.

For manufacturing performed at NASA-JSC facilities, work instructions shall consist of Detailed Process Instructions (DPI's).

At other facilities, the contractor shall be responsible for preparing, maintaining, and certifying written work instructions for contracted work. The contractor shall be responsible of ensuring that these work instructions meet the requirements of this specification.

### 6.2 **CLEANING PRIOR TO MARKING/ENGRAVING**

The markings/engravings shall be made on clean surfaces after final surface finishing, unless otherwise noted by this specification or the engineering drawing. The surface finish, if applied over the markings, shall not impair the legibility of the marking.

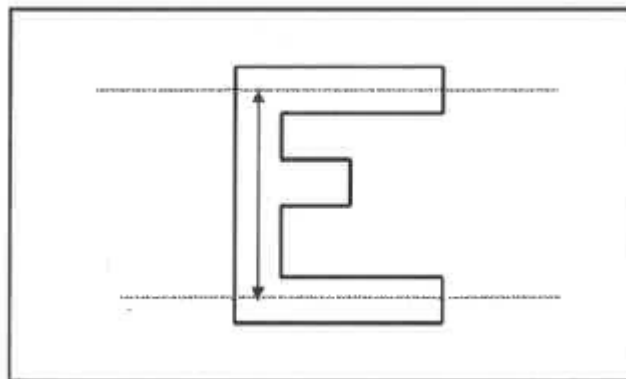
Surfaces shall be thoroughly cleaned with a non-detrimental solvent or liquid detergent prior to marking/engraving. Caution shall be taken to avoid the use of solvents, which may adversely affect the surfaces being cleaned.

### 6.3 **CHARACTER SIZE**

Character size shall be as specified on the engineering drawing.

#### 6.3.1 **CHARACTER HEIGHT**

Character height shall be measured from center-line to center-line of each character, as shown in Figure 7:



**Figure 7: Example of center-line measure of character height**

### **6.3.2 CHARACTER DEPTH**

If specified on the engineering drawing, character depth shall not be greater than the thickness of the coating or anodize on a metallic surface. The laser marking/laser engraving process shall not completely remove the coating or anodize. Marking/engraving shall be visually inspected for complete removal of the coating or anodize.

### **6.4 LOCATION & LEGIBILITY OF MARKING/ENGRAVING**

Location of marking/engraving shall be as specified on the engineering drawing.

The markings/engravings shall be legible under conditions of normal vision in daylight, or in equivalent illumination.

#### **6.4.1 Filled Impressions**

If specified on the engineering drawing, marking/engraving impressions shall be filled with an approved coating or RTV listed in Table 1.

The color of filled marking/engraving impressions shall be uniform and in contrast with the base material.

For flight hardware, a corrosion resistant primer shall be applied prior to application of coating for filling. The primer name shall be as specified on the engineering drawing in the parts list.

For non-flight and other ground support hardware, it is not necessary to use a corrosion-resistant primer prior to filling with a polyurethane paint or other coating.

### **6.5 PRODUCTION HARDWARE**

All production hardware shall be laser marked/laser engraved per the equipment settings approved by the qualification process. These settings include processing power, processing speed, image resolution, etc.

### **6.6 DEVIATIONS AND WAIVERS**

Any deviations or waivers regarding the use of this process specification shall be requested in writing. This request shall be directed to NASA-JSC/M&P with the appropriate justification and rationale. A written response will be provided upon such a request.

### **7.0 PROCESS QUALIFICATION**

The laser marking/laser engraving process shall be qualified for each material and configuration.

- a. A representative coupon shall be produced for inspection/evaluation. The representative coupon shall be of the same alloy, product form, heat treat condition, and finish as the production hardware. The representative coupon shall be processed in the same manner as the production hardware.
- b. The thickness of the representative coupon shall be the thickness of the thinnest section of the production hardware to be laser marked/laser engraving.
- c. The representative coupon shall be laser marked/laser engraved with all representative fonts and sizes anticipated for use in production hardware. The specific equipment settings (processing power, processing speed, image resolution, etc.) used for the representative coupon shall be documented in the process qualification record.
- d. If specified on the drawing, the laser marking/laser engraving process shall not completely remove the coating or anodize on the representative coupon.
- e. The markings/engravings on the representative coupon shall be legible under conditions of normal vision in daylight, or in equivalent illumination.
- f. If specified on the drawing, the color of filled marking/engraving impressions shall be uniform and in contrast with the base material of the representative coupon.
- g. The representative coupon shall be approved by the M&P engineering organization.
  - Inspection/evaluation of the marking/engraving and surrounding surfaces shall characterize factors such as cracking, contamination and spatter. Assessment of the contamination and the quantity of allowable spatter shall be discussed between NASA-JSC/M&P and the cognizant engineer.
  - Inspection/evaluation shall also characterize factors such as the depth achieved by the laser in a marked/engraved area, the presence and thickness of a coating or anodize, the width of the recast layer formed as an aftermath of the intense heat generated by the laser beam, local change in the microstructure given the heat affected zone, microcrack depth, distortion, etc. The representative coupon shall be cross-sectioned through the laser marking/laser engraving for this inspection/evaluation.
  - NASA-JSC/M&P shall provide a brief memo, as a minimum, with the results of the inspection/evaluation and the rationale for approving or rejecting qualification of the laser marking/laser engraving process. A detailed report of the inspection/evaluation results can be requested by the cognizant engineer.
- h. Upon NASA-JSC/M&P approval of the laser marking/laser engraving process, equipment settings shall be documented and retained in the procedure qualification record. Records of the equipment settings shall be retained in the laser marker/laser engraver program files.

## 7.1 PROCESS QUALIFICATION DOCUMENTATION

The vendor shall prepare and retain a permanent process qualification record (PQR) upon NASA-JSC/M&P approval of the process on a representative coupon. The PQR shall be made available to NASA-JSC/M&P for review and supplementation. The vendor shall include the following in the PQR:

- a. identification and calibration information (where applicable) of the laser marking/laser engraving equipment
- b. work instructions
- c. material specifications containing alloy type, product form, heat treat condition, and finish
- d. laser marking/laser engraving equipment settings such as processing power, processing speed, image resolution, etc.

NASA-JSC/M&P shall supplement the PQR with approved results of the inspection/evaluation on the laser marking/laser engraving.

## 8.0 PROCESS VERIFICATION

The vendor shall verify the process as follows:

- a. Verify laser marking/laser engraving equipment settings used to mark/engrave production hardware are approved and documented in the process qualification record.
- b. Verify that the laser marked/laser engraved surfaces and the surrounding surfaces on production hardware are free from cracks using a 10x magnification source.
- c. Verify adequate contrast between base material and laser marked/laser engraved surfaces on production hardware for legibility. If impression is to be filled, legibility shall be inspected post filling.
- d. Verify character size and location of laser marking/laser engraving on production hardware meets engineering drawing requirements.

## 9.0 TRAINING AND CERTIFICATION OF PERSONNEL

All personnel operating laser engraving systems shall receive proper training in their safe use and in producing quality products using the system. Training and certification records shall be kept.

## 10.0 DEFINITIONS

**Laser:** Light Amplification by Stimulated Emission of Radiation

**Laser Engraving:** Laser engraving is where the laser's beam is physically removing the surface material to expose a cavity which at eye level reveals an image. There are 3 types of Laser Engraving; etching, deep laser engraving and laser ablation. Each type is removing or vaporizing the surface material, the only difference is what's being removed and the depth you are going down into the material.

- *Deep Laser Engraving* is a deep mark, often a requirement for either regulatory reasons or for parts that will be exposed to harsh conditions either physically or environmental, for example identification marks on parts exposed to corrosive chemicals.
- *Laser Ablation* is engraving where we remove a surface coat, like paint or anodizing, to expose either another layer underneath or the bare surface material. This is a process common on ID Tags and Plates, automotive parts, switches, knobs and backlit buttons.
- *Laser Etching* is a more shallow type mark, .001" for example.

**Laser Marking:** Laser marking is where the beam is interacting with the surface of the material and slightly altering its properties or appearance. Laser marking is an option for bar coding, UID codes, QR Codes, Logos and other identification needs.