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APPLYING DATA MATRIX IDENTIFICATION SYMBOLS ON AEROSPACE PARTS

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MEASUREMENT SYSTEM IDENTIFICATION:
Inch-Pound/Metric

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DOCUMENT HISTORY LOG

Status	Document Revision	Approval Date	Description
Baseline		2001-06-01	Baseline Release
Revision	A	2002-09-23	Incorporates metric unit equivalent in parentheses beside all English measurement units. Section 4.1 has a statement added that when measurement terms are expressed, English units are used as the "Primary" expression and Metric units are used as "Secondary" expression, shown in parentheses beside the English units. Section 4.1 has a statement added that data matrix symbols that are applied to the substrate of a part and subsequently covered with paint, foam, and other protective coatings SHALL be applied by the same methods identified in this Standard and its related Handbook, NASA-HDBK-6003A, Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods/Techniques. Section 4.2 has modified text that changes the data content order from part number-CAGE-serial number to CAGE-part number-serial number, making this Standard consistent with MIL STD 130 and other direct part marking standards. It also defines that an asterisk is used to separate those data fields when ASCII format is used and a dash when human readable identification is used. Figure 1 was rearranged to be consistent with the text of Section 4.2.
Revision	B		Incorporated changes stemming from DoD retrofit part marking development and DPM flight verification tests Added Appendices A, B, and C Input into new template; made editorial changes

FOREWORD

This standard is published by NASA to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item. Use of this standard is the responsibility of the user.

This standard is approved for use by NASA Headquarters and NASA Centers, including Component Facilities.

This standard establishes uniform requirements for applying Data Matrix identification symbols to parts used on NASA programs/projects using direct part marking (DPM) methods and techniques.

Requests for information, corrections, or additions to this standard should be submitted via "Feedback" in the NASA Technical Standards System at http://standards.nasa.gov.

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Rex D. Geveden
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Approval Date

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APPLYING DATA MATRIX IDENTIFICATION SYMBOLS ON AEROSPACE PARTS

1. SCOPE

This standard and its related handbook, NASA-HDBK-6003, Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods/Techniques, were developed to provide NASA and its contractors with instructions to safely apply Data Matrix identification symbols to aerospace parts using these new DPM methods and techniques. Both the standard and the handbook were created by representatives from the major automatic identification and data capture (AI/DC) manufacturers, government, and aerospace user groups under a collaborative agreement with NASA. The standard has been approved for use by NASA Headquarters for all field installations, and is intended to provide a common framework for consistent practices across NASA programs.

Revision B of this standard includes updates stemming from the DoD/National Center of Manufacturing Sciences (NCMS) Retrograde Part Marking Program as approved by the Assistant Under Secretary of Defense, and the United States Coast Guard (USCG) Data Matrix Direct Part Marking Flight Verification Program, which was sanctioned by the Flight Safety Critical Aircraft Part Problem Action Team (FSCAP PAT) and U.S. Congress Aircraft Safety Committee. Revision B planning had called for the incorporation of information resulting from the Materials-International Space Station-Experiment (MISSE), which exposed the Data Matrix Symbol markings to low-earth orbit (LEO) environments. However, due to delays in the retrieval of the MISSE experiment, information related to marking processes certified for LEO are to be incorporated into a later revision of this document. MISSE program information is included in Appendix A.

1.1 Purpose

This standard establishes uniform requirements for applying Data Matrix identification symbols to parts used on NASA programs/projects using DPM methods and techniques. Overall program/project requirements related to the use of the Data Matrix symbol include: symbol criteria, marking method selection, marking surface preparation, marking location, protective coatings, marking environments, and mark-quality verification standards. This document does not specifically address the marking of human-readable characters or temporary part identification markings (bands, labels, or tags). On new programs, human-readable characters can be applied using the same marking methods defined in this standard. Data Matrix symbols can be added to parts used on existing programs if there is adequate area to accommodate the mark and the structural integrity of the part is not compromised.

This standard is intended to provide general requirements for applying Data Matrix identification symbols safely onto products using permanent DPM methods and techniques. The standard addresses symbol structure only as it relates to marking and reading limitations. Technical specifications related to the Data Matrix symbol are found in AIM International, Inc., technical specification titled “International Symbology Specification – Data Matrix.” Technical information on how to apply the markings is addressed in NASA-HDBK-6003, Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods/Techniques.

1.2 Applicability

This standard is applicable to NASA programs/projects using DPM methods and techniques.

This standard may be cited in contract, program, and other Agency documents as a technical requirement or as a reference for guidance. Except where noted as mandatory, individual provisions of this standard may be tailored (i.e., modified or deleted) by contract or program specifications to meet specific program/project needs and constraints. Tailoring must be formally documented as part of program/project requirements and approved.

This standard recommends the use of Data Matrix symbol marking to support updates to Automated Identification Technology (AIT) systems used to provide program managers with real-time hardware status. The standard provides engineering practices for NASA programs and projects. Human-readable markings applied to NASA aircraft maintained under Federal Aviation Administration (FAA) certificate such as Part 121 or Part 135 shall comply with Title 14 of the Code of Federal Regulations. Data Matrix marking are used to identify the following:

- Calibration items
- Critical fasteners
- EEE parts
- Fracture-critical parts
- Hazard analysis items
- Items requiring periodic maintenance
- Limited-life items
- Pilferage Items
- Repair-limited items
- Restricted-use items
- Safety-critical Items
- Temporary installations
- Other items identified with paint dots or assigned date codes, lot numbers, member numbers, or serial numbers for safety, reliability, maintainability or quality assurance purposes, including items not currently serialized due to size limitations associated with the applications of human- readable marking.

Environmental, health, and safety impacts in processes and materials shall be considered when employing identification marking methods and techniques. Alternative, "environmentally friendly" materials, which contain low/no volatile organic compounds (VOCs), shall be considered when determining the appropriate method/technique for each marking application. Many types of ink contain VOCs, such as methyl ethyl ketone, xylene, and toluene, which are principal components in atmospheric reactions that form ozone and other photochemical oxidants. Exposures to VOC-containing materials have health impacts, which include eye and respiratory irritation, headache, dizziness, memory impairment, neurotoxicity, and cancer.

2. APPLICABLE DOCUMENTS

2.1 NASA DOCUMENTS

NASA-HDBK-6003, Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods/Techniques

2.2 ELECTRONICS INDUSTRY ALIANCE/CONSUMER ELECTRONICS ASSOCIATION

EIA/CEA 706 - Component Marking Standard

EIA/CEA 802 - Product Marking Standard

(Copies of these documents are available from Consumer Electronics Association (CEA), 2500 Wilson Blvd., Arlington, VA 22201-3834, http://www.ce.org/)

2.2.1 EEE manufactures shall mark NASA parts and components in accordance with EIA/CEA 706 and EIA/CEA 802 as specified in the contract or order using the most appropriate data format suggested in this document.

3. DEFINITIONS AND ACRONYMS

3.1 Acronyms

AI/DC - Automatic Identification and Data Capture

AIM – Automatic Identification Manufacturers

AIT – Automated Identification Technology

ANSI – The American National Standards Institute. A non-government organization responsible for the coordination of voluntary national (United States) standards. ANSI, 11 West 42nd Street, New York, NY 10036, Telephone: 212.642.4900, Telefax: 212.302.1286

AO – Atomic Oxygen

ASTM – American Society for Testing and Materials

ATA – Aircraft Transportation Association

CAGE Code – Commercial and Government Entity Code

CCD – Charged Coupled Device

CMOS – Complementary Metal Oxide Semiconductor

CO_2 – Type of laser using carbon dioxide gas as the lasing medium

DoD – Department of Defense

DPM – Direct Part Marking

DUNS – Data Universal Numbering System

EAN – International Government Entity

ECC – Error Correction Codes or Error Check and Correction: the Data Matrix code can be printed in 15 error-correction levels

ECM – Electrochemical Machining

EEE - Electrical, Electronic and Electro-mechanical

EI – Enterprise Identifier

EPA – Environmental Protection Agency

EVA – Extravehicular Activity

FAA – Federal Aviation Administration

FSCAP PAT – Flight Safety Critical Aircraft Part Problem Action Team

GALE – Gas Assisted Laser Etch

HRI – Human-Readable Identification

ISO – International Standards Organization

KHz – Kilohertz (1000 cycles of oscillation per second)

LASER – Light Amplification by Stimulated Emission of Radiation

LBM – Laser Beam Machining

LENS – Laser Engineered Net Shaping

LEO – Low Earth Orbit

LISI – Laser-induced Surface Improvement

LIVD – Laser-induced Vapor Deposition

MEK – Methyl Ethyl Ketone

MISSE – Materials International Space Station Experiment

NASA – National Aeronautics and Space Administration

NCMS – National Center of Manufacturing Sciences

Nd:YAG – Type of laser using a Neodymium Yttrium Aluminum Garnet crystal as the lasing medium

Nd:YVO_4 – Type of laser using a Neodymium-Doped Yttrium Vanadate crystal as the lasing medium

NSCM – NATO Supply Code for Manufacturers

PECs – Passive Experiment Containers

PN – Part Number

RMS – Roughness Measurement Scale

UCC – Uniform Code Council

USCG – United States Coast Guard
UV – Ultra Violet

VOCs – Volatile Organic Compounds

WAD – Work Authorization Document

XRF – x-Ray Fluorescence

3.2 Definitions

2-D – Two Dimensional

Age Life Item: Any item designated as having a limited useful life regardless of whether it is a limited operating life, limited shelf life, operating life sensitive, or combinations of these. This includes fluids, elastromers, and polymers, where appropriate.

ASCII: American Standard Code for Information Interchange. The code is used in the transmission of data. The code consists of eight data-bits used to code each alphanumeric character and other symbols.

Bad-Read: A decodes operation that results in the output of inaccurate data.

Bar Code: A patterned series of vertical bars of varying widths used by a computerized scanner for inventory, pricing, etc.

Binary Value: A mark on the substrate surface indicates the binary of one. The absence of a mark or a smooth surface surrounding a cell center point indicates the binary value of zero.

Bit (Binary Digit): The basic unit of information in a binary numbering system. The binary system uses 1s and 0s.

Centerline of a Row or Column: The line positioned parallel to, and spaced equally between, the boundary lines of the row or column.

Character (Data character): A letter, digit, or other member of the ASCII character set.

Character Set: Character available for encodation in a particular automated identification technology.

Contrast: The grayscale difference between two areas of color.

Data Element: The smallest named item of information that can convey data, analogous to a field in a data record or a word in a sentence.

Data Element Separator: The special character used to separate data elements in a data format.

Data Matrix Symbol: A 2-D array of square or round cells arranged in contiguous rows and columns. In certain Error Checking and Correction (ECC)200 symbols, data regions can be separated by alignment patterns. The data region is surrounded by a finder pattern (AIM – Data Matrix).

Density (Matrix Density): The number of rows and columns in a scanned matrix symbol.

Depth of Etch: The distance from the surface of the substrate to the bottom of the recess created by an etching process.

Direct Part Marking: Markings applied directly to a part's surface using intrusive or non-intrusive identification techniques.

Dot: A localized region with a reflectance, which differs from that of the surrounding surface.

Edge: A dramatic change in pixel brightness values between regions. It is the point(s) that has the greatest amount of contrast difference (change in intensity values) between pixels.

EEE Parts: EEE (electrical, electronic, and electromechanical) parts such as: capacitors, connectors, diodes, inductors, microcircuits, relays, resistors, switches, transistors, and transformers.

Electrolyte: The solution formed by water and a selected salt(s) and used as the conductor between an object and electrode in an electro-chemical marking process. Selected electrolytes also have the ability to "color" the mark due to the chemical reaction that takes place between the metal and the electrolyte.

Enterprise Identifier: A code used to define each entity location that has its own unique, separate, and distinct operation. An enterprise may be an entity such as a manufacturer, supplier, depot, program management office, or a third party. An enterprise identifier is a code uniquely assigned to an enterprise by a registered issuing agency. An issuing Agency is an organization responsible for assigning a non-repeatable identifier to an enterprise, i.e., Dun & Bradstreet's Data Universal Numbering System (Duns) number, Uniform Code Council (UCC)/EAN International Government Entity (EAN) Company Prefix, Allied Committee 135 Commercial and Government Entity (CAGE) number, or Coded representation of the North American Telecommunication Industry Manufacturers, Suppliers, and Related Service Companies (ANSI T1.220) Number.

Error Checking and Correction (ECC): Mathematical algorithms used to identify symbol damage and reconstruct the original information, based upon the remaining data in a damaged or poorly printed code. Reed Solomon and convolution are two such techniques.

Field of View: The maximum area that can be viewed through the camera lens or viewed on the monitor.

Finder Pattern of a Data Matrix Code Symbol: A perimeter to the data region. Two adjacent sides contain dots in every cell: these are used primarily to define physical size, orientation and symbol distortion. The two opposite sides are composed of cells containing dots in alternate cells (AIM – Data Matrix).

Good-mark: A good mark is one that can be decoded (read) successfully 10 out of 10 tries with the reader in focus and positioned at a 90-degree angle to the target (± 20 degrees) under any light condition.

Good-read: A successful decoding attempt that results in the output of accurate data.

Grayscale: The assignment of a digital value to a degree of light intensity. The shades of gray are used by the computer to reconstruct an image. A common scale is 256 shades of gray, with 0 being black and 255 being white.

Hardness: A measure of the resistance of a material to surface indentation or abrasion; may be considered as a function of the stress needed to produce some specified type of surface deformation. There is no absolute scale for hardness; therefore, to express hardness quantitatively, each type of test has its own scale of arbitrarily defined hardness. Indentation hardness can be measured by Brinell, Rockwell, Vickers, Knoop, and Scleroscope hardness tests.

Human-Readable Identification: The letters, digits or other characters associated with specific symbol characters that are incorporated into linear bar code or 2-D symbols.

Intensity: The average of the sum total of grayscale value.

Intrusive Marking: A mark made by any device designed to alter a material surface to form a human or machine-readable symbol. These marking devices include, but are not limited to, devices that abrade, burn, corrode, cut, deform, dissolve, etch, melt, oxidize, or vaporize a material surface.

License Tag Number: The information contained with the symbol character set to uniquely identify the component. As a minimum, the information contains the manufacturer's CAGE code followed by an asterisk (ASCII separator) and trace code (lot, member, or serial number).

Manufacturer: Producer or fabricator of component or the supplier in a transaction if the supplier is the warrantor of the component.

Mark: Refers to a Data Matrix symbol that has been applied to a material surface using a permanent marking method.

Matrix: A set of numbers, terms, or items arranged in rows and columns.
Matrix Density: The number of rows and columns in a matrix.

No-Read: An unsuccessful decoding attempt that results in no data output.

Non-intrusive Marking: A method of forming markings by adding material to a surface. Non-intrusive marking methods include ink jet, laser bonding, liquid metal jet, silk screen, stencil, and thin film deposition.

Part Identification Data: Markings used to relate parts to their design, manufacturing, test, and operational histories.

Permanent Marking: Intrusive or non-intrusive markings designed to remain legible beyond the normal service life of an item.

Photo-Stencil: A silk-screen type fabric coated with a photo-resist compound that can be fixed by Ultra Violet (UV) radiation and easily washed from the fabric where unexposed. The patterns opened in the fabric are the images to be marked (stenciled, etched, or colored) on the substrate.

Pilferage Items: Items, such as tools, that are easily stolen.

Pixels: Picture elements. In a camera array, pixels are photoelectric elements capable of converting light into an electrical charge.

Quiet Zone: Areas of high reflectance (spaces) surrounding the machine-readable symbol. Quiet zone requirements may be found in application and symbology specifications. Sometimes called "Clear Area" or "Margin."

Reader: A general term used to describe an optical-based or sensor-based symbol capture device. Optical-based reader is another name for a CCD or CMOS camera. Sensor-based readers, used to capture symbol images hidden from view are similar to optical readers, except that the CCD or CMOS is replaced with a sensor that can discern the symbol from its background. Sensor-based readers utilize capacitance, thermal, x-ray, ultrasound, micro-impulse radar, or other similar sensing mechanisms to detect and capture hidden images.

Resolution: The measure of how small a feature the camera can distinguish in its field of view. Camera resolution is determined in its field of view. The number of pixels within the CCD array determines camera resolution. The more pixels used to capture the image, the higher the resolution or quality of the image. Since the number of pixels is fixed, the smaller the field of view, the higher the image resolution. For example, a 1-inch (25.4 mm) field of view photographed by a 640 x 480 camera with a resolution of .0015-inch (0.04 mm) per pixel; a ½-inch (12.7 mm) field of view has a resolution of .00078-inch (0.02 mm) per pixel.

Safety Critical Item: Facility, support, test, and flight systems containing:

- Electrical equipment that operates in the area where flammable gases, fluids, or solids are located
- Equipment used for handling program hardware
- Equipment used for personnel walking and work platforms
- Flammable, toxic, cryogenic, or reactive elements or components
- High temperatures
- High voltages
- Hydraulics and pneumatics
- Pressurized vessels, lines, and components
- Propellants, including cryogenics
- Ordnance and explosive devices, or devices used for ordnance safeing and explosive checkout
- Radiation sources
- Any item, which through its use, may incur injury or bodily harm to the operator and/or the general public

Structure: The order of data elements in a message.

Substrate: The material (paper, plastic, metal, etc.) upon which a symbol is marked.

Supplier: The trading partner in a transaction that provides the component (e.g., manufacturer, distributor, reseller, etc).

Symbology: A machine-readable pattern composed of a quiet zone, finder pattern, symbol characters (which include special functions and error detection and/or correction characters) needed for a particular symbology.

Temporary Identification: Markings designed to be removed or separated from items before they reach the end of their life cycle.

Thermal Stencil: Similar to the photo-stencil. In this case, the fabric is coated with a compound, which can be opened by a thermal printer to form the desired images.

Traceability: For purposes of this document, traceability is defined as the ability to relate historical documentation to parts using part identification numbers.

4. REQUIREMENTS

4.1 General Requirements

4.1.1 2-D Symbol

The Data Matrix symbol is preferred for direct-part identification marking on NASA programs/projects unless otherwise directed by contract. The symbols are applied in addition, and in close proximity to, the human-readable identification (HRI) markings currently used. On new programs/projects, the HRI and symbol-marking are applied simultaneously and by the same method whenever practical. The Data Matrix symbol is a 2-D matrix symbology approved by the AIM for direct-part marking. There are two symbol types: ECC 000 – 140 with several available levels of convolutional ECC, and ECC 200 which uses Reed-Solomon error correction. For new NASA applications, ECC 200 shall be required. ECC 000 – 140 should only be used in closed applications where a single party controls both the production and reading of the symbols, and is responsible for overall system performance. The characteristics of Data Matrix symbol are defined within the Uniform Symbology Specification for Data Matrix.

When process parameters of symbol size, height, or depth are expressed in linear terms on drawings and other documents, metric equivalents are included. English units serve as the “Primary” expression and Metric units are “Secondary” expression, shown in parentheses beside the English units.

Data Matrix symbols that are applied to the substrate of a part and subsequently covered with paint, foam, and other protective coatings use the same methods identified in this standard and its related Handbook, NASA-HDBK-6003, Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods Techniques. The imaging of subsurface identification symbols relies primarily on the ability of a detection device to sense and image the hidden symbol. Intrusive methods of marking normally benefit detection devices that sense differences in surface regularity. Non-intrusive or additive methods normally benefit detection devices that sense substances that exhibit a different characteristic from that of the substrate.

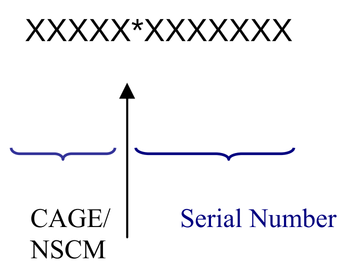
Examples of sensor-based readers that image intrusive and non-intrusive markings through coatings are shown in Appendix B.

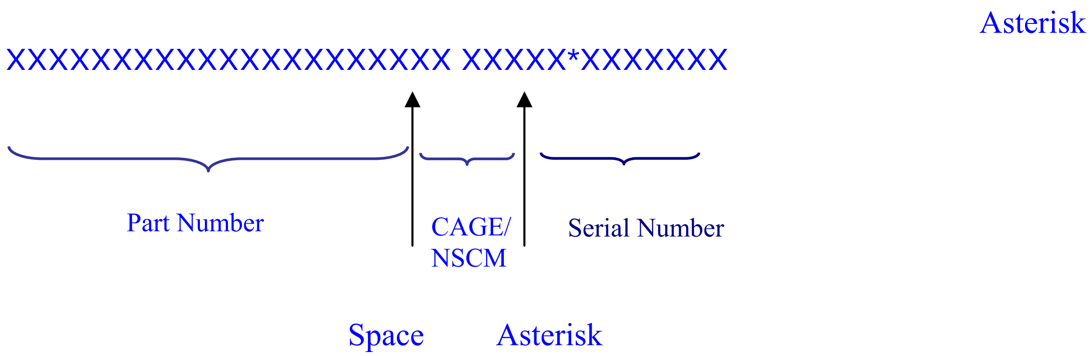
Elemental taggant technology, used in combination with an x-ray fluorescence (XRF) detection system, is a useful method for identifying and authenticating a part. x-ray fluorescence may be used for detecting elements from the Periodic Table in known concentrations to represent subsurface identification characters. It is recommended that the resulting spectral data output be expressed in the approved Data Matrix format for automatic decoding by software in the detection system. The selected elements may be applied as taggant constituents of the Data Matrix symbol or as a standalone identifier.

The spectral data output of standalone selected taggant elements, the constituent substances in a symbol mark, the substrate itself, or any combination of these constitute valid-part identification only if these conventions are formally accepted and the acceptance is documented. Examples of XRF readers are shown in Appendix C.

4.1.2 2-D Symbol Content

The full-part identification data to be encoded into the 2-D symbol consists of a part number (PN) that is typically 15 to 21 characters, followed by a space to separate it from the unique part identifier; Enterprise Identifier (EI); an asterisk ASCII separator for machine-readable identification symbols, and a unique lot, member, or serial number. In instances where space is prohibitive, the PN can be excluded from the data content and an abbreviated traceability number used. The traceability number or unique part identification number consists of the users, EI, and unique seven-digit lot number or serial number, separated by an asterisk in the machine-readable symbol. These data encoding and marking options provide program managers with the ability to use a more damage-resistant symbol (larger data cells) over a greater range of part sizes. Data Matrix symbols that are subsequently covered with paint, foam, or other protective coatings shall have the same symbol content requirements as symbols that remain visible throughout their life cycles. Figure 4.1-1 illustrates NASA's preferred data content formats.





Data format to be used in areas providing sufficient marking area.

Data format to be used where marking area is insufficient to place a symbol containing complete data content.

FIGURE 4.1-1. Preferred 2-D Symbol Data Format

4.1.3 2-D Symbol Shape

The Data Matrix symbol can be created in square and rectangular formats, the square format being preferred (see Figure 4.1-2). However, for some linear-shaped parts such as pipes, lines, narrow part edges, etc., it may be more desirable to use a rectangular-shape symbol. The intent is to use a symbol shape providing the largest-size data cells.

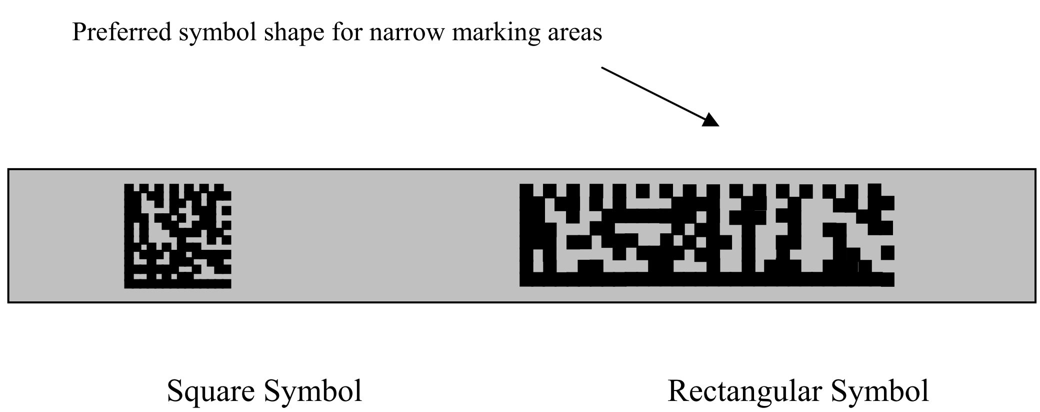


FIGURE 4.1-2 Data Matrix Symbol Shapes

4.1.4 2-D Symbol Size

Data Matrix symbols can be produced in sizes ranging between 4microns (0.0001016 mm) square to 2feet (609.6 mm) square, with the limiting factors being the capability and fidelity of the marker. Symbol size is not an issue using fixed-station readers that are configured to accept different-size lens or with hand-held readers configured with variable or multiple lenses. Hand-held readers configured with fixed lenses, to reduce cost and complexity, are generally limited to reading symbols within specific size ranges, i.e., read small symbols, large symbols, or some compromise zone. In general, fixed-lens hand-held readers are used in applications where symbol size is fixed and variable or multiple-lens readers used in applications requiring the use of different size 2-D symbols and/or bar codes. Regardless of lens type, hand-held readers are generally limited to reading symbols containing individual data cells that measure 0.0075 inch (0.12 mm) across or larger. The overall symbol size of less than 1-1/2inches (38.1 mm) on the outside dimension of the longest side shall be required. For purposes of this standard, symbol sizes are divided into three categories: micro symbols containing data cells that are < 0.008inch (0.203mm), typical symbols with data cells ranging between 0.008inch and 0.034inch (0.203mm to 0.863mm), and macro-size symbols with data cells ≥0.035inch (0.889mm).

4.1.5 Part Identification Conflicts

Any conflicts between HRI and the Data Matrix symbol markings shall be resolved, including update of documentation and databases.

4.2 DETAILED REQUIREMENTS

4.2.1 Marking Method Selection Factors

Data Matrix symbol marking method selection is influenced by a number of different factors. These factors need to be analyzed closely to ensure that the appropriate marking method is selected. The factors to be considered are summarized as follows.

4.2.1.1 Part Function

Part function is an important consideration in marking method selection. Non-intrusive marking methods are recommended for safety-critical parts, i.e., parts which could fail resulting in hazardous conditions.

Written approval shall be required for the use of intrusive markings in safety-critical areas.

4.2.1.2 Part Geometry

Flat surfaces are preferred over curved surfaces for marking. When it is necessary to apply Data Matrix symbol markings to cylindrically shaped parts (both concave or convex), a rectangular symbol shall be applied that is sized to fit within the reflective band of light that emanates from the spine of the curve or 5 percent of the circumference. This band of light typically occupies 16 percent of the diameter of the curve under normal room light and can increase in size under bright light conditions. Figure 4.2-1 illustrates the proper method for marking curved surfaces.

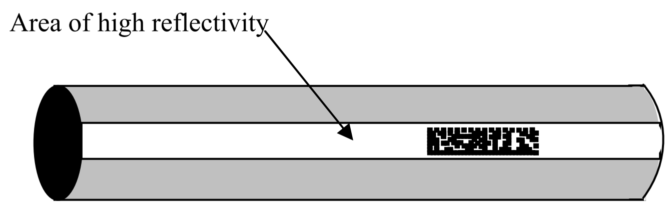


FIGURE 4.2-1 Proper Placement of Data Matrix Symbols on a Curved Surface

Highly polished metal surfaces that are RMS 0 to 8 should be textured (reference 4.2.3) to reduce glare prior to marking. The textured area should extend one symbol width beyond the borders of the marking as illustrated in Figure 4.2-2.

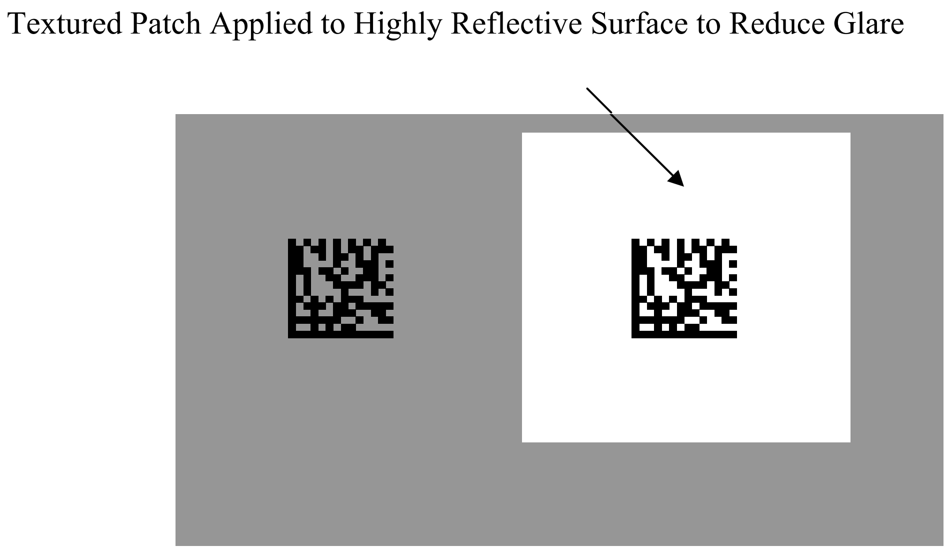


FIGURE 4.2-2 Textured Patch Applied to Reduce Glare

4.2.1.3 Part Size

Part size does not become a factor in 2-D symbol marking until the available marking area is reduced to below 1/4-inch (6.35 mm) square. Below this level, the number of marking options is reduced significantly. Table 4.2-1 provides typical symbol sizes by marking process.

TABLE 4.2-1 Symbol Sizes by Marking Process

Symbol Size Categories	Marking Process	Typical Data Cell Size (Ascending Order)	Data Format		
			P/N, EI and S/N - Typically 29 Characters (24x24 Matrix)	EI and S/N - Typically 13 Characters (18x18 Matrix)	S/N Only - Typically 7 Characters (12x12 Matrix)
Micro - <0.008-inch data cells	Laser Marking – Short Wave Length (Excimer)	0.0002-inch (.005mm)	0.004-inch (0.102mm)	0.003-inch (0.076 mm)	0.002-inch (0.051mm)
Typical - 0.08-inch to 0.034 data cells	Laser-Shot Peening	0.009-inch (0.238mm)	0.216-inch (5.286mm)	0.162-inch (4.114mm)	0.108-inch (2.743mm)
	Stencil (Photo-Process)	0.010-inch (0.254mm)	0.240-inch (6.096mm)	0.180-inch (4.572mm)	0.120-inch (3.048mm)
	Laser Bonding	0.010-inch (0.254mm)	0.240-inch (6.096mm)	0.180-inch (4.572mm)	0.120-inch (3.048mm)
	Laser Marking	0.010-inch (0.254mm)	0.240-inch (6.096mm)	0.180-inch (4.572mm)	0.120-inch (3.048mm)
	Stencil (Mechanical Cut)	*0.020-inch (0.508mm)	0.480-inch (12.192mm)	0.360-inch (9.144mm)	0.240-inch (6.096mm)
	Adhesive Dispensing	0.020-inch (0.508mm)	0.480-inch (12.192mm)	0.360-inch (9.144mm)	0.240-inch (6.096mm)
	Dot Peen*	*0.022-inch (0.558mm)	0.528-inch (13.411mm)	0.396-inch (10.058mm)	0.264-inch (6.705mm)
	LISI	0.024-inch (0.609mm)	0.576-inch (14.630mm)	0.432-inch (10.972mm)	0.288-inch (7.315mm)
	Stencil (Laser Cut)	*0.024-inch (0.609mm)	0.580-inch (14.732mm)	0.440-inch (11.176mm)	0.288-inch (7.315mm)
	Abrasive Blast	0.025-inch (0.635mm)	0.600-inch (15.240mm)	0.450-inch (11.430mm)	0.300-inch (7.620mm)
	Ink Jet	0.030-inch (0.762mm)	0.720-inch (18.288mm)	0.540-inch (13.716mm)	0.360-inch (9.144mm)
Macro – ≥0.035-inch	Engraving/Milling	*0.040-inch (1.016mm)	0.960-inch (24.384mm)	0.720-inch (18.288mm)	0.480-inch (12.192mm)
	Fabric Weaving	0.040-inch (1.016mm)	0.960-inch (24.384mm)	0.720-inch (18.288mm)	0.480-inch (12.192mm)
	LENS	0.040-inch (1.016mm)	0.960-inch (24.384mm)	0.720-inch (18.288mm)	0.480-inch (12.192mm)
	Fabric Embroidery	0.045-inch (1.143mm)	1.080-inch (27.432mm)	0.810-inch (20.574mm)	0.540-inch (13.716.mm)
	Cast, Mold & Forge	0.060-inch (1.524mm)	1.440-inch (36.576mm)	1.080-inch (27.432mm)	0.720-inch (18.288mm)

* Includes spacing between data cells

4.2.1.4 Material Type

The primary factor in the selection of an appropriate marking method is the material being marked. Table 4.2-1 provides a listing of common marking methods by material type.

4.2.1.5 Material Hardness

Material hardness does not have an effect on the application of non-intrusive or non-contact marking methods. Hardness does have a direct effect on tool wear when engraving, milling, or stamp impression (dot or laser-shot peen) marking methods are used. Tool wear and tool damage shall be monitored closely on metals or metal alloys hardened above 35 Rockwell C.

TABLE 4.2-2 Marking Method Selection

	METALLICS								NON-METALLICS								
MATERIAL TO BE MARKED / MARKING PROCESS	Aluminum	Anodized	Beryllium	Carbon Steel	Copper	Brass	Magnesium	Titanium	Ceramics	Glass	Cloth	Painted	Plastics	Rubber	Teflon	Wood	Others
Abrasive Blast	•	•		•	•	•	•	•	•			•	•		•		•
Adhesive Dispensing	•	•	•	•	•	•	•	•	•	•	1	•	•	•		•	•
Cast, Forge or Mold	•	•	•	•	•	•	•	•	•				•	•			
Dot Peen	•			1	•	~~1~~ •						1	•				
Electro-Chem Coloring	•	•	•	•	•	•	•	•									
Electro-Chem Etching	•	•	•	•	•	•	•	•									
Embroidery											•						
Engraving/Milling	•	•		•	•	•						1	•			•	
Laser Bonding	•		•	•		•	•	•	•	•							
Laser - Short Wave Lengths	•	1	•	•	•		•	•	•	•		1	•	•	•	•	•
Laser - Visible Wave Lengths	1	1		•	1	•						1	•				
Laser – Long Wave Lengths		1								•		1				•	
Laser Shot Peening	•	1	2	2	•	2	2	•				1	•				
LENS	•	1	•	•	•	•	•	•									
LISI	•	2		•	•		2	2									
Ink Jet	•	•	•	•	•	•	•	•	•	•	1	•	•	•			•
Silk Screen	•	•	•	•	•	•	•	•	•	•		•	•	•		•	•
Stencil	•	•	•	•	•	•	•	•	•	•		•	•	•		•	•
Thin Film Deposition	•	•	•	•	•	•	•	•	•	•			•	•			•

• = Acceptable marking process for noted material
1 = Contact Engineering before proceeding
2 = Marking method still under development

Given the number of variables to be considered, selection of a marking device based on speed is accomplished on a case-by-case basis.

4.2.1.6 Surface Color

Dark-colored markings are generally applied to light surfaces and light markings applied to dark surfaces. The minimum contrast difference between the symbol and its substrate that can be reliably read is 20 percent as shown on a standard gray scale comparator (see Figure 4.2-3). The minimum acceptable contrast level is 40 percent at point of marking to allow for degradation over time in the use environment (reference paragraph number 4.2.1.8). In situations where surface colors change (camouflage patterns), care must be taken to apply marks in an area of uniform color.

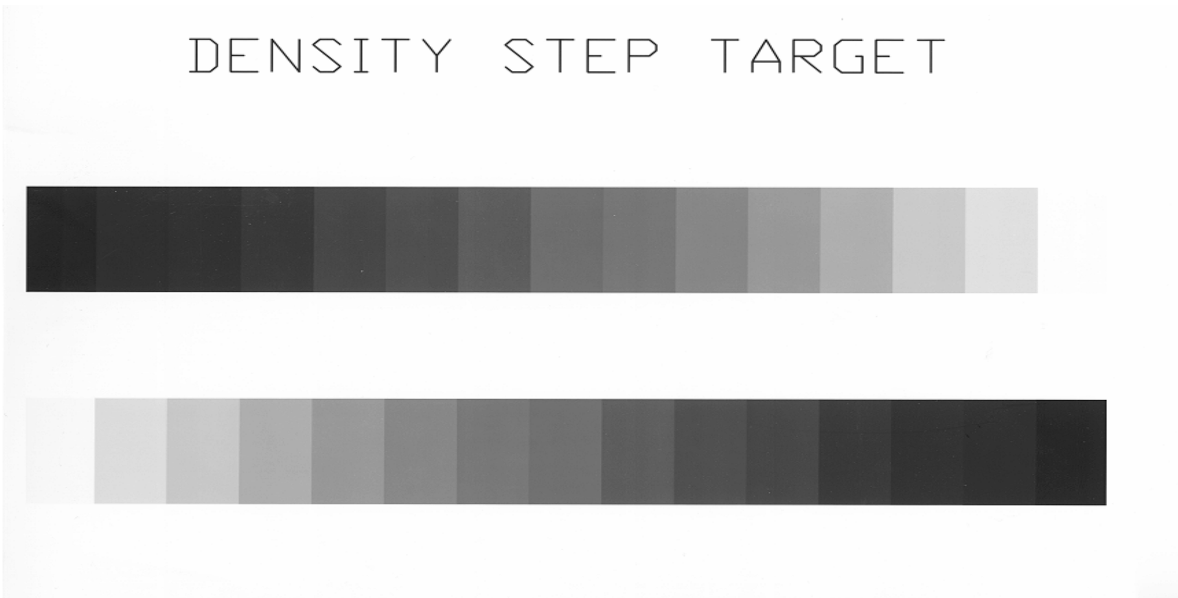


FIGURE 4.2-3 Typical Gray Scale Comparator

4.2.1.7 Surface Roughness/Finish

Symbol marking should be limited to surface roughness levels averaging between 8 and 250 micro-inches (millionth of an inch [0.0000254 mm]); unless the marking method utilized is specifically designed for use on extreme rough surfaces (reference Table 4.2-3). Surfaces that fall outside of acceptable surface roughness levels can also be resurfaced as defined in section 4.2.1.8 or marked with labels, tags, or identification plates (Figures 4.2-4 and 4.2-5).

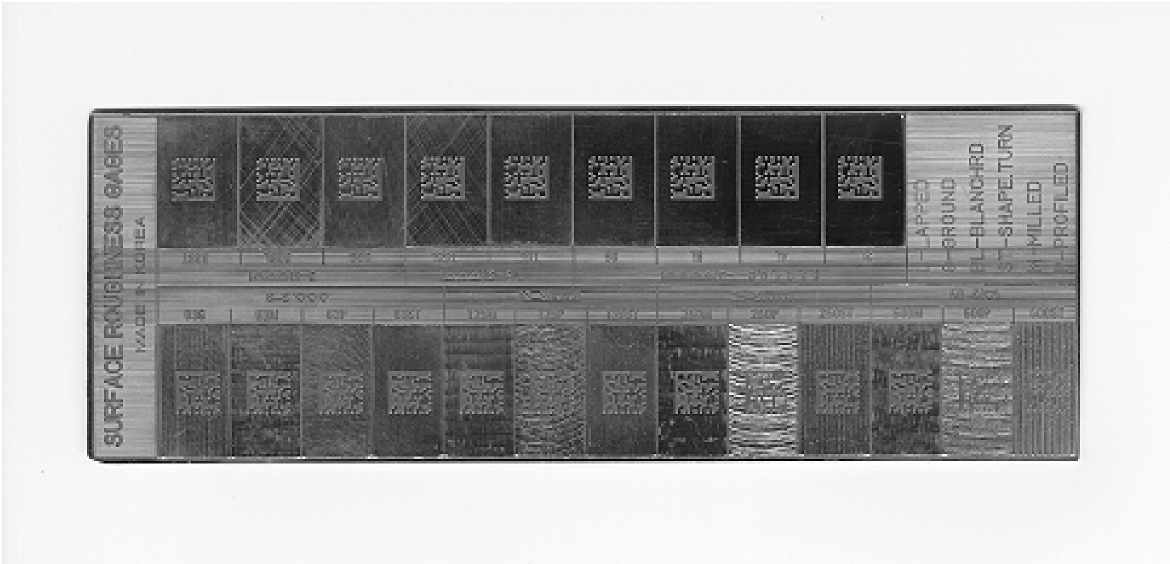


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FIGURE 4.2-4 Typical Microfinish Comparator

TABLE 4.2-3 Ranges of Average Surface Roughness by Processing Method

Processing Category	Processing Method	Roughness Average (R_a) μin.											
		1	2	4	8	16	32	63	125	250	500	1000	2000
Machining	Lapped												
	Ground												
	Blanchard												
	Shape Turned												
	Milled												
	Profiled												
Nonabrasive Finishing	ECM												
	EDM												
	LBM												
Blasting	Grit blasting												
	Sand Blasting												
	Shot Peening												
Cast Surfaces	Die												
	Investment												
	Shell Mold												
	Centrifugal												
	Permanent Mold												
	Non-ferrous Sand												
	Ferrous Green Sand												

Optimum Data Matrix Marking Range

Cast surfaces present a unique symbol decoding challenge, because the surface irregularities (pits) create shadows that can be misinterpreted by the decoding software such as dark data cells. Consequently, individual data cells in the symbol must be larger than the surface irregularities so that the decoding software can differentiate between the two features. The data cells contained in the symbol must be increased in size in direct proportion to the average surface roughness-level to ensure successful decoding. Some particular marking methods are capable of producing large raised or indented cell sizes that are much larger than surface irregularities on extremely rough surfaced parts. Figure 4.2.5 and Table 4.2-4 provide a formula and minimum cell size restrictions developed to aid in determining minimum symbol sizes to be used on cast surface. Otherwise, the area to be marked must be treated to provide a smoother substrate for the mark. Figure 4.2-6 shows the relationship between cell size and cast surface roughness.

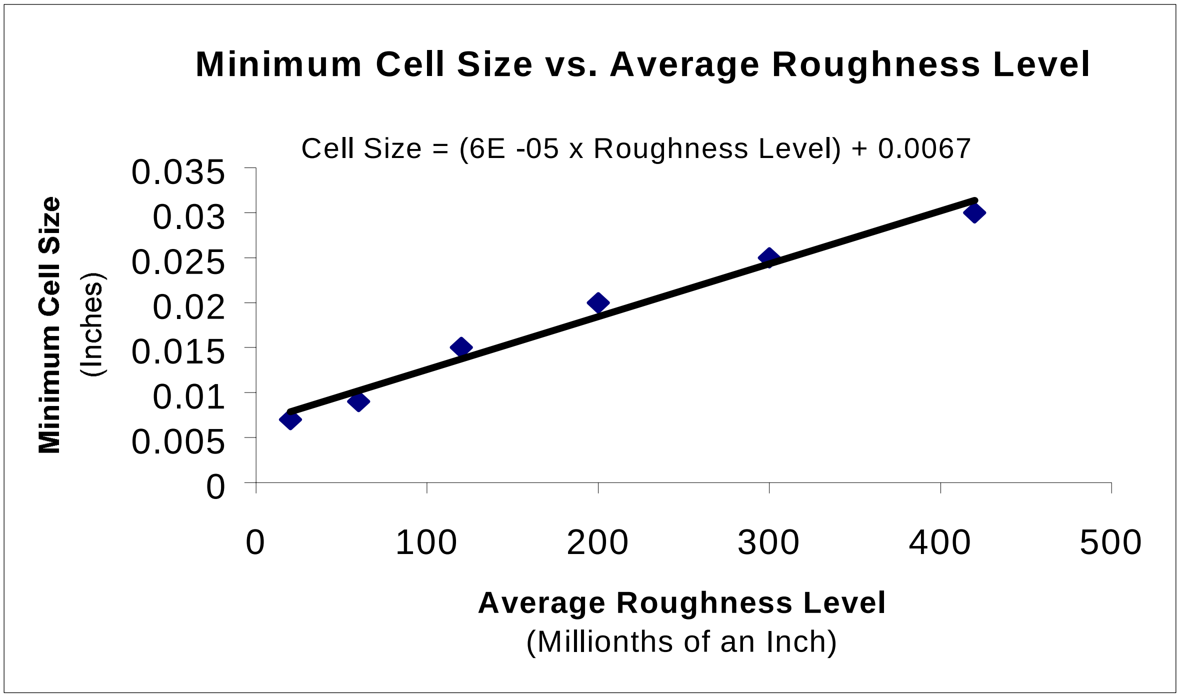


FIGURE 4.2-5 Minimum Cell Size vs. Average Roughness Level

TABLE 4.2-4 Minimum Readable Cell Size by Roughness Level

Average Roughness Level (millionths of an inch [0.0000254 mm])	Minimum Cell Size (Inches)
20	0.01 (0.19 mm)
60	0.01 (0.23 mm)
120	0.02 (0.38 mm)
200	0.02 (0.51 mm)
300	0.03 (0.64 mm)
420	0.03 (0.76 mm)

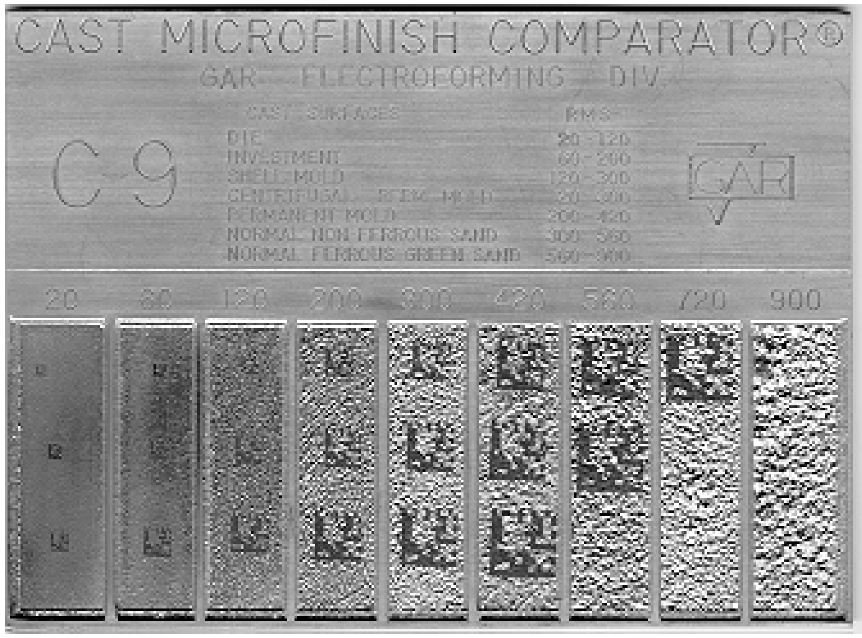


FIGURE 4.2-6 Comparator Showing Relationship Between Cell Size and Cast Surface Roughness

4.2.1.8 Surface Thickness

Surface thickness must be considered when applying intrusive markings to prevent deformation or excessive weakening of the part. The degree of thickness for intrusive marking shall be directly related to the heat, depth, or force applied. In most applications, the marking depth shall not exceed 1/10 the thickness of the part (10x mark/etch). Table 4.2-5 defines the maximum practical marking depth that can be obtained using intrusive marking methods. Part thickness is generally not a consideration when applying non-intrusive markings.

TABLE 4.2-5 Minimum Recommended Substrate Thickness By Marking Method

Marking Method	Maximum Marking Depth	Minimum Part Thickness
Laser Bonding	Surface Mark	0.001-inch (0.03 mm)
Electro-Chemical Coloring	0.0002-inch (0.06 mm)	0.002-inch (0.05 mm)
Abrasive Blast	0.0003-inch (0.08 mm)	0.003-inch (0.08 mm)
Acid Etch – Stencil	0.0005-inch (0.01 mm)	0.005-inch (0.13 mm)
Chemical Coloring – Stencil	0.001-inch (0.03 mm)	0.010-inch (0.25 mm)
Laser Annealing	0.001-inch (0.03 mm)	0.010-inch (0.25 mm)
Laser Shot-Peening	0.002-inch (0.05 mm)	0.020-inch (0.51 mm)
Electro-Chemical Etch	0.002-inch (0.05 mm)	0.020-inch (0.51 mm)
Laser Etch	0.003-inch (0.08 mm)	0.030-inch (0.76 mm)
LISI	0.004-inch (0.10 mm)	0.040-inch (1.02 mm)
Dot Peen	0.004-inch (0.10 mm)	0.040-inch (1.02 mm)
Laser Engraving	0.125-inch (31.75 mm)	1.250-inch (31.75 mm)
Micro-Milling	0.125-inch (31.75 mm)	1.250-inch (31.75 mm)

4.2.1.9 Operating Environment/Age Life

Users should verify that the marking method selected produces a mark that can survive in its intended environment and retain a minimum grade of "C" while in use as defined in ISO-15415.

Durability and longevity shall be established. Specifications to control processes and marking material quality to pass durability tests shall be developed for the environment intended. Tests typically used for this purpose are identified in Table 4.2-6.

TABLE 4.2-6 Marking Method Test Specifications

Test	Specification Number	Specification Title
Abrasion Resistance	ASTM D-4060-01	Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
Adhesion	ASTM D3359 02	Standard Test Methods for Measuring Adhesion by Tape Test
Atmospheric Acid Pollution Resistance	ASTM D1308-02E1 (with addition of sulfuric acid testing)	Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes
Bending Test	ASTM D522-93a (2001)	Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings
	ASTM D3794 00	Standard Guide for Testing Coil Coatings
Boiling Water	ASTM D870 02	Standard Practice for Testing Water Resistance of Coatings Using Water Immersion
Chemical Resistance	Not Applicable	1 hour immersion in appropriate chemical
Corrosion Resistance	ASTM B117 03	Standard Practice for Operating Salt Spray (Fog) Apparatus
Hardness	ASTM D3363 00	Standard Test Method for Film Hardness by Pencil Test
Impact	ASTM D2794-93 (2004)	Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
Mar Resistance	ASTM D673-93ae1 (withdrawn)	Standard Test Method for Mar Resistance of Plastics
Thermal	ASTM D2485-91 (2000)	Standard Test Methods for Evaluating Coatings For High Temperature Service
Transparency	ASTM D1003-03 (not active)	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics Transparency
Ultraviolet Exposure	ASTM G154	Standard Practice for Fluorescent for UV Exposure of Nonmetallic Materials
Water Resistance	ASTM D870 02	Standard Practice for Testing Water Resistance of Coatings Using Water Immersion

TABLE 4.2-6 Marking Method Test Specifications (continued)

Test	Specification Number	Specification Title
	ASTM D2247 02	Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity
Water Vapor	ASTM E96 00e1	Standard Test Methods for Water Vapor Transmission of Materials
Weathering	ASTM G155-00ae1	Standard Practice for Operating Xenon-Arc Light Apparatus for Exposure of Non-metallic Materials
Note: ASTM Specifications can be acquired from the American Society For Testing And Materials, West Conshohocken, PA.		

4.2.1.10 Production Rates (Marking Time).

Process times for marking a symbol on the surface of a part are affected by a variety of factors including, but not limited to, the following:

- Symbol size
- Symbol density
- Marking device
- Mask or mold production (if required)
- Data input
- Part movement and positioning
- Part holding/clamping (if required)
- Operator proficiency

4.2.2 Marking Environments

Government testing has been conducted to assess the effects of environments on the survivability of the part marking processes described in this standard. During these tests, part markings were subjected to all of the typical environments encountered during both ground and flight operations (including LEO); and part servicing, repair, and overhaul. These environments are summarized in Tables 4.2-7 and 4.2-8, and are provided to aid users during the marking selection process.

4.2.2.1 Operational Environments

4.2.2.1.1 Ground and Sub-orbital Flight

- Abrasion per ASTM D4060-95 or G132-96
- Chemical Exposure
  - Cleaners such as Methyl Ethyl Keytone (MEK)
  - Deicers
  - Dye Penetrant
  - Fuel such as JP4/5

- Grease
- Hydraulic Fluid
- Liberating Oils
- Paint Stripper

- Foreign Object Damage (Minor)
- Salt Fog Spray per ASTM B117-95
- Temperature Extremes: -30°F to +140°F, engines components up to + 2000°F
- Ultra-Violet Light per ASTM G23-96 or G26-95

4.2.2.1.2 Low-earth Orbit

- Exposure to atomic oxygen (AO)
- Irradiation with high-energy particles
- Exposure to solar ultra-violet (UV) radiation
- Impact by space debris or meteoroid particles
- Temperature extremes

4.2.2.2 Service and Repair Environments

- Acid Etch per TT-C-490
- Alkaline Cleaning per TT-C-490
- Detergent Wash per TT-C-490
- Emulsion Cleaning per TT-C-490
- Mechanical/Abrasion Cleaning per TT-C-490
- Solvent Wash per TT-C-490
- Steam Cleaning per TT-C-490
- Ultra-Sonic Cleaning per ASTM G131-96
- Vapor Degreasing per TT-C-490
- Penetrant Inspection per MIL-STD-6866 (media MIL-I-25135E)

4.2.2.3 Overhaul Environments

- Abrasion Blast per MIL-STD-1504 (Plastic Media - MIL-P-85891)
- Abrasion Blast per MIL-STD-1504 (Glass Media - MIL-G-9954)
- Abrasion Blast per MIL-STD-1504 (Garnet Media - MIL-A-21380)
- Abrasion Blast per MIL-STD-1504 (Aluminum Oxide Media)
- Abrasion Blast per MIL-STD-1504 (Grit Media - MIL-G-5634)
- Temper Etch per MIL-STD-867
- Acid Dip (Phosphoric or Sulfuric Acid)
- Flame Spray Strip per MIL-STD-869
- Heat Treat to 2000 degrees F. per MIL-STD-6875
- HVOF Strip per MIL-STD-871
- IVD Strip per MIL-STD-871

- Paint Strip per MIL-STD-871 (T.O. 4S-1-182)
- Plate Strip per MIL-STD-871
- Shot Peen per AMS-S-13165, intensity 0.006A to 0.010A, Shot S-230 to S-330

TABLE 4.2-7 Ground, Sub-orbital, and Low-Earth Orbit Environments

Marking Process	Part Environments															
	Ground and Sub-Orbital Operations (DoD Supplied)											Low Earth Orbit Operations (NASA Supplied -MISSE)				
	Abrasion	Chemicals - Deicer	Chemicals- Fuels	Chemicals - Grease	Chemicals - Hydraulic Fluid	Chemicals - Lubricating Oil	Foreign Object Damage (minor)	High Heat (Engines) +2000°F	Temperature: -30°F to 140°F	Ultra-Violet	Salt Spray	Atomic oxygen	High Energy Particles	Ultra-Violet (UV)	Debris & Meteoroid Impact	Temperature Extremes
Cast Forge and Mold	X	X	X	X	X	X	X		X	X	X	X		X		X
Dot Peen	X	X	X	X	X	X		R	X	X	X	X		X		X
Electro-Chem. Coloring		X	X	X	X	X			X	X						
Electro-Chem. Etch With Color Added*																
Ink Jet*				X												
Laser Bonding		X	X	X	X	X	X		X	X	X					
LENS		X		X												
Laser–Coloring				X												
Laser–Engraving (Direct)	X	X	X	X	X	X	X	R	X	X	X	X		X		X
Laser–Engraving (Coat & Remove) *				X												
Laser–Etch (Coat and Mark)				X												

TABLE 4.2-7 Ground, Sub-orbital, and Low-Earth Orbit Environments

Marking Process	Part Environments															
	Ground and Sub-Orbital Operations (DoD Supplied)											Low Earth Orbit Operations (NASA Supplied -MISSE)				
	Abrasion	Chemicals - Deicer	Chemicals - Fuels	Chemicals - Grease	Chemicals - Hydraulic Fluid	Chemicals - Lubricating Oil	Foreign Object Damage (minor)	High Heat (Engines) +2000°F	Temperature: -30°F to 140°F	Ultra-Violet	Salt Spray	Atomic oxygen	High Energy Particles	Ultra-Violet (UV)	Debris & Meteoroid Impact	Temperature Extremes
Laser–Etch (Direct)	X	X	X	X	X	X	X		X	X	X					
Laser–Etch (Gas Assisted)				X												
Laser – Induced Surface Improvement		X	X	X	X	X	X		X	X	X					
Laser–Induced Vapor Deposition																
Laser-Shot Peen		X	X	X	X	X			X	X	X					
Mechanical Engraving	X	X	X	X	X	X	X	X	X	X	X	X		X		X
Silk Screen*								U								
Stencil-Chemical Coloring								U								
Stencil–Ink*								U								
Stencil–Thermal Spray		X	X	X	X	X			X							
Paper Labels	U	U	U	U	U	U		U	X							U
Polymeric Labels				X	X	X		U	X	X	X					U
Metallic Tags, Bands and Nameplates								U	X	X	X					

Legend: X = Marking remains readable, R = Marking can be restored to readable status, U = Marking rendered unusable, Blank = Testing Not Completed
*Clear coat required, ** Incorporated for comparison purposes

TABLE 4.2-8 Service, Repair, and Overhaul Environment

Marking Process	Part Environments																						
	Service & Repair (DoD Supplied)									Overhaul (DoD Supplier)													
	Acid Etch	Alkaline Cleaning	Detergent Wash	Emulsion Cleaning	Mechanical/Abrasion	Solvent Wash	Steam Cleaning	Ultra-Sonic Cleaning	Vapor Degreasing	Penetrate Inspection	Abrasive Blast - Plastic	Abrasive Blast - Glass	Abrasive Blast - Garnet	Abrasive Blast – Al Ox	Abrasive Blast - Grit	Acid Dip	Flame Spray	HVOF Strip	IVD Strip	Paint Strip	Plating Strip	Shot Peen	Heat Treat
Cast Forge and Mold (Metal)	X	X	X	X		X	X	X	X	X							X			X	X		X
Dot Peen		X	X	X	X	X	X	X	X	X													
Electro-Chem. Coloring																							
Electro-Chem. Etch																							
Engraving	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R	X	X	X	X	X	R
Ink Jet*																							
Laser Bonding																							
LENS		X	X	X	X	X	X	X	X	X													
Laser–Coloring																							
Laser–Engraving (Direct)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	R	X	X	X	X	X	R
Laser–Engraving (Coat & Remove)																							
Laser–Etch (Coat and Mark)																							
Laser–Etch (Direct)		X	X			X	X		X	X													
Laser–Etch (Gas Assisted)																							
Laser - Induced Surface Improvement		X	X	X		X	X	X	X	X													
Laser–Induced Vapor Deposition																							
Laser-Shot Peen																							
Silk Screen*	U				U					U	U	U	U	U	U	U	U	U	U				U
Stencil–Ink*	U				U					U	U	U	U	U	U	U	U	U	U				U
Stencil–Thermal Spray																							
Paper Labels**	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Polymeric Labels**			X		U	X	X	X			U	U	U	U	U	U	U	U		U	U		U
Metallic Tags, Bands and Nameplates**			X	X		X	X	X		X								U					

Legend: X = Marking remains readable, R = Marking can be restored to readable status,
U = Marking rendered unusable, Blank =Testing not completed
* = Clear coat required, ** = Show for comparison purposes

4.2.2.3.5 Cleaning

Cleaning processes used for removing soils and contamination are varied, and their effectiveness depends on the requirements of the specific application. In selecting a metal cleaning process, many factors must be considered, including:

- The nature of the soil to be removed
- The substrate to be cleaned (i.e., ferrous, non-ferrous, etc.)
- The importance of the condition of the surface to the end use of the part
- The degree of cleanliness required
- The existing capabilities of the available facilities
- The environmental impact of the cleaning process
- Cost considerations
- The total surface area to be cleaned
- Effects of previous processes
- Rust inhibition requirements
- Material handling factors
- Surface requirements of subsequent operations, such as phosphate conversion coating, painting, or plating.

4.2.3 Marking Surface Preparation

Prior to marking, operators shall determine if surface preparation is required. This analysis shall address:

- Surface finishes that cause excessive amounts of shadowing and/or glare
- Surfaces that do not provide the necessary contrast for decoding
- Safety-critical parts that cannot be marked using intrusive marking methods
- Materials that are not conducive to marking with the user's preferred marking method

The most common methods utilized to prepare surfaces for marking are additives and coatings.

4.2.3.1 Additives

Specialized additives can be mixed with metal alloys and thermoplastic formulations to enhance and optimize marking contrast. These additives, mixed into the substrate material, increase the ability of the substrate material to absorb specific wavelengths of laser light, but do not generally affect overall material performance.

4.2.3.2 Coatings

Coatings are used to modify a part surface to improve its characteristics and/or provide corrosion protection. Coatings can be utilized to aid part marking by:

- Smoothing rough surfaces to reduce the effects of shadowing
- Providing contrast for part surfaces that are within gray scale mid-range
- Dulling highly polished surfaces to reduce glare

- Providing a surface that can be removed with intrusive markings to expose a substrate of contrasting color
- Providing a surface that can be discolored or textured with an intrusive marking method to produce the required level of contrast
- Serving as a media for marking using a stencil as a mask

The most commonly used processes to coat surfaces prior to marking are:

4.2.3.2.1 Dip, Barrier and Conversion Coating

Dip, barrier, and chemical conversion coating is a term that encompasses a family of processes used to prevent corrosion. These coating processes include:

- Anodizing
- Babbitting
- Ceramic Coatings and Linings
- Chromate Conversion Coatings
- Elastomeric Coatings for Automotive Plastics
- Electrodeposited Coatings
- Hot-dip Coatings
- Hot-dip Galvanized Coatings
- Painting
- Phosphate coatings
- Porcelain enameling
- Rust-preventative Compounds

4.2.3.2.2 Laser-induced Surface Improvement (LISI)

LISI is a laser process utilized to instill stainless properties to carbon steel. The process differs from laser bonding in that the coating material is mixed with the substrate to form an improved alloy with high corrosion-resistant properties. The process can also be used to improve the wear characteristics of aluminum surfaces. LISI-treated surfaces can be discolored or removed to form a Data Matrix symbol.

4.2.3.2.3 Plating and Electroplating

Plating and electroplating processes are divided into two categories: Electro Deposition and Non-electrolytic deposition processes. The processes associated with these categories are listed as follows:

- Electro Deposition:
- Cadmium Plating
- Copper and Copper Alloy Plating
- Chromium Alloy Plating
- Decorative Chromium Plating
- Electroforming

- Gold Plating
- Indium Plating
- Industrial (Hard) Chromium Plating
- Iron Plating
- Lead Plating
- Multi-Layer Alloy Plating
- Nickel Plating
- Platinum-Group Plating
- Pulsed-Current Plating
- Selective (Brush) Plating
- Silver Plating
- Tin and Tin Alloy Plating
- Zinc Plating

Non-electrolytic:

- Electro-less Alloy Plating
- Electro-less Copper Plating
- Electro-less Gold Plating
- Electro-less Nickel Plating
- Mechanical Plating

4.2.3.2.4 Vacuum-controlled Atmosphere Coating and Surface Modification Processes

Vacuum- controlled atmosphere coatings are general terms that encompass Thermal Spray, Chemical Vapor Deposition, Physical Deposition, Diffusion, and Pulsed-laser Deposition processes. This family of processes is used to modify surfaces by depositing material to part surfaces that are to be marked. Vacuum-controlled atmosphere coatings and surface modification processes can be used as a media application method for use with stencil marking.

4.2.3.3 Machining

Machining is normally performed to bring the average surface roughness level to less than 250 micro-inches. Reader tests have proven that surfaces rougher than 250 micro-inches produce shadows that adversely affect hand-held reader performance when using symbols in the micro to standard sizes (1/6-inch [4.23-mm] to 1/2-inch [12.7-mm] square). The most commonly used machining methods for surface smoothing are described below.

4.2.3.3.1 Blanchard (Ground)

Grinding removes material from a part with a grinding wheel or abrasive belt.

4.2.3.3.2 Lapping

Lapping is performed by rubbing two surfaces together, with or without abrasives, to obtain extreme dimensional accuracy or superior surface finish.

4.2.3.3.3 Milling

Milling is performed using a rotary tool, with one or more teeth, that removes material as the part moves past the rotating cutter.

4.2.3.3.4 Profiling

Profiling is a milling process that duplicates external or internal profiles in two dimensions. A tracing probe follows a 2-D template, and through electronic or air-actuated mechanisms, controls the cutting spindles in two mutually perpendicular directions. The spindles – usually more than one – are set manually in the third dimension.

4.2.3.3.5 Shape Turning

Shape turning is designed to remove material by forcing a single-point cutting tool against the surface of a rotating work piece. The tool may or may not be moved toward or along the axis of rotation while it removes material.

4.2.3.4 Texturing

Texturing is commonly used to roughen surfaces prior to marking to reduce the amount of glare emanating from the surface. Glare has been shown to have an adverse effect on the ability of 2-D readers to image and decode symbols of any size.

Surface texturing shall bring the surface finish to an average roughness level above 8 micro-inches as defined by ASME B46.1 and MIL-STD-10A. Texturing of part surfaces prior to marking is normally performed by the following.

4.2.3.4.1 Abrasive Blast

A process for finishing of an abrasive directed at high velocity against a part. Abrasive blasting methods include grit blasting, sandblasting, and shot blasting.

4.2.3.4.2 Electrochemical Machining (ECM)

ECM is the process in which a controlled metal is removed by anodic dissolution. Direct current passes through a flowing film of conductive solution that separates the part from the electrode/toll. The part is the anode, and the tool is the cathode.

4.2.3.4.3 Electro Discharge Machining (EDM)

EDM is metal removal by rapid-spark discharge between polarity electrodes, one on the part, and the other on the tool, separated by a gap distance of 0.0005 to 0.035 inches (0.013 to 0.89 mm). The gap is filled with dielectric fluid and metal particles, which are melted, in part vaporized, and expelled from the gap.

4.2.3.4.4 Laser Beam Machining (LBM)

Lasers are used to texture surfaces by melting the surface to refine its appearance. Lasers' effectiveness depends on the requirements of the application. In selecting a metal-cleaning process, many factors must be considered, including the following.

- The nature of the soil to be removed

- The substrate to be cleaned (i.e., ferrous, non-ferrous, etc.)
- The importance of the condition of the surface to the end use of the part
- The degree of cleanliness required
- The existing capabilities of the available facilities
- The environmental impact of the cleaning process
- Cost considerations
- The total surface area to be cleaned
- Effects of previous processes
- Rust-inhibition requirements
- Material-handling factors
- Surface requirements of subsequent operations, such as phosphate conversion coating, painting, or plating

4.2.3.5 Cleaning Processes used with DPM

The most commonly used cleaning processes used in conjunction with DPM are listed below.

4.2.3.5.1 Acid Cleaning

Acid cleaners more diluted than acid-pickling solutions are effective for removing light, blushing rust, such as the rust on ferrous metal parts in high humidity or short-time exposure to rain. Acid deoxidizing solutions, specifically designed for use on aluminum, shall be used before electroplating or chemical coating. Various organic acid-based solutions, such as citric acid, are used to remove rust from stainless steels, including the 400 series and the precipitation-hardening steels.

4.2.3.5.2 Alkaline Cleaning

Alkaline cleaning is a commonly used method for removing many soils from the surface of metals. Soils removed by alkaline cleaning include oils, grease, waxes, metallic fines, and dirt. Alkaline cleaners are applied by either spray or immersion facilities and are usually followed by a warm-water rinse. A properly cleaned metal surface optimizes the performance of a coating that is subsequently applied by conversion coating, electroplating, painting, or other operations. The main chemical methods of soil removal by alkaline cleaner are saponification, displacement, emulsification and dispersion, and metal-oxide dissolution.

4.2.3.5.3 Compliance Wipe

Compliance wipe solvents shall be used to remove contaminants from parts before undergoing manufacturing operations that require clean surfaces; such as bonding, sealing, painting, welding, plating, specialized surface treatment, etc. Traditional wipe solvents include:

- Methyl ethyl ketone
- Methyl isobutyl ketone
- Trichloroethene (trichloroethylene)
- Tetrachloromethane (perchloroethylene)
- 1,1,1,-trichloroethane (methyl chloride)
- Acetone
- Toluene

- Dichloromethane (methylene chloroform)
- Tetrachloromethane (carbon tetrachloride)
- Benzene
- Xylene
- Ethylene glycol ethers
- Diethylene glycol ethers
- 1,1,2-troichloro-1,2,2-trifluoroethane chlorinated fluorocarbon (CFC-113)
- Combination of these materials

The U.S. Environmental Protection Agency (EPA) has classified these materials as being either hazardous air pollutants or ozone-layer depleting substances that have been or are to be banned from use in the future. Wipe-solvent materials shall meet EPA requirements for the emission of volatile organic compounds, the reduction or elimination of hazardous air pollutants, and the elimination of ozone-layer depleting substances. Alternative materials are identified in MIL-C-38736.

Other solvents are obtainable under the following commercial brand names: Exxon Corporation's Isopar C, Isopar E, Isopar G, Isopar, H, Isopar, K, Isopar L, Isopar M, Isopar, V, Axarel 9100 (isoparaffins) and 3M company's PF-5050, PF-5052, Pf,5060, PF 5070 and PF5080 (perflurocarbons).

4.2.3.5.4 Emulsion Cleaning

Emulsion cleaning is an industrial cleaning process that uses an organic solvent as the main active agent. The solvent is usually a hydrocarbon of distilled petroleum dispersed in water. The emulsion, which alone is potentially volatile, is suspended in a nonvolatile aqueous vehicle. Most emulsion cleaners include emulsifying agents, and some are aided by surfactants. Emulsion cleaners are generally used when alkaline or acid cleaners are not applicable.

4.2.3.5.5 Mechanical Cleaning Systems

Mechanical cleaning systems are available for most industrial production applications to remove contaminants and prepare the work surface for finishing or coating. Typical uses include:

- Removing rust, scale, dry solids, mold, sand, ceramic shell coatings, or dried paint
- Roughening surfaces in preparation for bonding, painting, enameling, or other coating substances.
- Removing large burrs or weld spatter
- Developing a uniform surface finish, even when slightly dissimilar surfaces are present
- Removing flash from rubber or plastic molding operations
- Carving or decorative etching of glass, porcelain, wood, or natural stone such as granite or marble

The types of parts that can be mechanically cleaned are:

- Ferrous and nonferrous castings
- Forgings or stampings

- Steel plate, strip, or structural shapes
- Welds and other fabrications of ferrous and nonferrous materials
- Aluminum, magnesium, zinc permanent-mold, or die-cast items
- Thermoplastic or thermoset plastics
- Steel bar stock and wire rod
- Precision molded rubber parts
- High-alloy dies and molds for rubber, plastic, glass, or metal parts
- Miscellaneous exotic parts

Mechanical cleaning systems use various types of abrasive materials that are energized or propelled against the work surface or part using one of the following methods:

- Airless centrifugal blast blade- or vane-type wheels
- Compressed air, direct-pressure dry blast nozzle systems
- Compressed-air, indirect-suction (induction) wet- or dry-blast nozzle systems
- Aggressive vibratory systems
- Media tumbling systems
- Part-on-part tumbling system

4.2.3.5.6 Molten Salt Bath Cleaning

Molten salt baths are anhydrous, fused chemical baths used at elevated temperatures for industrial cleaning applications, including the following:

- Removal of organic polymers and coatings
- Dissolution of sand, ceramic, and glassy materials
- Stripping of plasma carbide coatings

In addition, molten salt baths may be used to pre-treat cast-iron surfaces before brazing, bonding, or marking. Molten salt baths for cleaning applications are chemically active or reactive fluids with unique process capabilities. The chemistry involved during cleaning applications ranges from simple dissolution of contaminants to more complex reactions involving the thermo-chemical oxidation of organics and the electrolysis of molten salts.

4.2.3.5.7 Pickling and Descaling

Pickling is the most common process used to remove scale from steel surfaces. The term, “Pickling,” refers to the chemical removal of scale by immersion in an aqueous acid solution. The process originated in the late 1700s when sheets of steel were de-scaled by immersion into vats of vinegar. Variations are possible in the type, strength, and temperature of the acid solutions used, depending on the time constraints (batch versus continuous operations), and the thickness, composition, and physical nature (cracks) of the scale. Pickling is applicable to many types of forgings and castings, for merchant bar, blooms, billets, sheet, strip, wire, and tubing.

4.2.3.5.8 Solvent Cold-cleaning and Vapor-degreasing

Solvent cleaning is a surface-preparation process that is especially adept at removing organic compounds such as grease or oil from the surface of a metal. Most organic compounds are easily made soluble by an organic solvent and removed from the parts. In some cases, solvent cleaning before other surface preparations can extend the life of cleaning operations and reduce costs. Solvent cleaning is often used to prepare parts for marking. Before marking, solvent cleaning is usually followed by an alkaline wash or another similar process that provides a hydrophilic surface. Solvent cleaning can also be used to remove water from parts marked with plating, laser-bonding, or similar marking processes.

Solvent cleaning can be accomplished in room-temperature baths or by using vapor-degreasing techniques. Room temperature solvent-cleaning is referred to as "cold cleaning." Vapor degreasing is the process for cleaning parts by condensing solvent vapors of a solvent on parts. Parts may also be degreased by immersion in the hot solvent, as well as by exposure to the solvent vapor. Drying is accomplished by evaporating the solvent from the parts, as they are withdrawn from the hot-solvent vapor. In cold cleaning, the parts are dried at room temperature or by the use of external heat, centrifuging, air blowing, or absorptive medium. The use of many industrial solvents is being severely restricted because of health, safety, and environmental concerns.

4.2.3.5.9 Ultrasonic Cleaning

Ultrasonic cleaning (Ref. STM G-131) involves the use of high-frequency sound waves above 18 kHz to remove a variety of contaminates from parts immersed in aqueous media. The contaminants can be dirt, oil, grease, buffing/polishing compounds, and mold-release agents. Materials that can be cleaned include metals, glass, ceramics, etc. Ultrasonic agitation can be used with a variety of cleaning agents. Ultrasonic cleaning removes tough contaminants without damaging the substrate. It provides excellent penetration and cleaning in the smallest crevices and between tightly spaced parts in a cleaning tank.

4.2.3.5.10 Classification and Selection of Cleaning Processes

Classification and selection of cleaning processes are defined in ASM Surface Engineering Handbook, Vol. 5.

4.2.3.5.11 Cleanliness Verification

Appropriate levels of cleanliness can be verified using the test methods defined in ASTM G-120 and ASTM G-144.

4.2.4 Marking Methods

DPM is generally suggested in applications where:

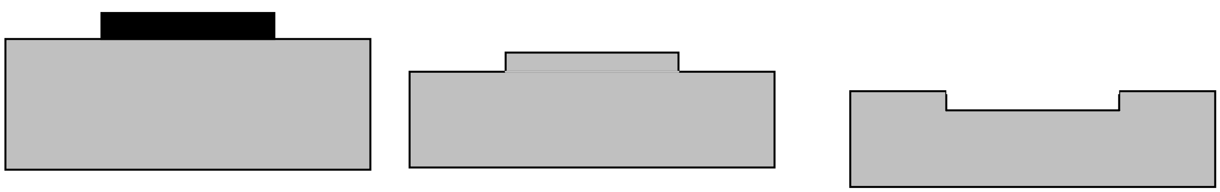
- Traceability is required after the product is separated from its temporary identification
- The part is too small to be marked with bar-code labels or tags.
- The part is subjected to environmental conditions that preclude the use of add-on identification
- Identification is required beyond the expected life of the part to preclude further use

DPM can be divided into two categories: non-intrusive and intrusive. Figures 4.2-7 and 4.2-8 provide examples of cross-sectional views of direct part markings described in this section.

4.2.4.1 Non-intrusive Marking Methods

Non-intrusive markings, also known as additive markings, are produced as part of the manufacturing process or by adding a layer of media to the surface using methods that have no adverse effect on material properties. These methods include:

- Adhesive dispensing
- Cast, Forge, or Mold
- Ink Jet
- Stencil Markings
- Thin-film Deposition
- LENS
- Silk Screen Marking



Additive Markings – Adhesive dispensing, Ink Jet, Laser Bonding, LENS, Silk Screen, Stencil, and Thin Film Deposition

Raised Markings – Cast, Forge, or Mold

Recessed Markings – Cast, Forge, or Mold

Figure 4.2-7 Data Matrix Symbol Non-Intrusive Marking Cross Section

4.2.4.2 Intrusive Marking Methods

Intrusive markings that alter a part's surface (abrade, cut, burn, vaporize, etc.) are considered to be controlled defects and if not applied properly can degrade material properties beyond a point of acceptability. Consequently, some intrusive markings, especially direct laser, are generally not used in safety critical applications without appropriate metallurgical testing. Typical intrusive marking methods include:

- Abrasive Blast
- Direct-laser Marking
- Dot Peen (Stamp Impression)
- Electro-Chemical Etching (electrolytic surface coloring or metal removal processes)
- Engraving/Milling
- Fabric Embroidery
- Laser-shot Peening

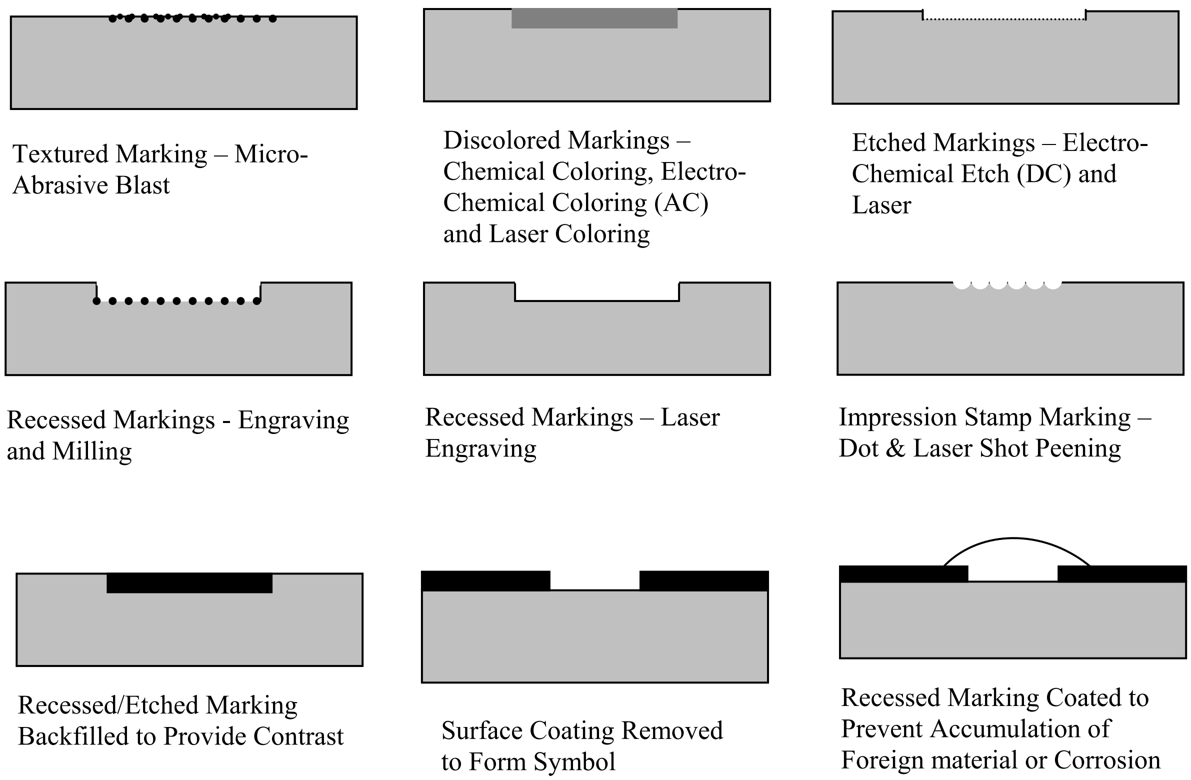


FIGURE 4.2-8 Data Matrix Symbol Intrusive Marking Cross Sections

4.2.4.3 Marking Method Requirements

The specific marking method shall be selected to ensure product integrity. Material degradation and hazard analysis studies shall be required for safety-critical part applications. Detailed instructions related to the application of DPM methods are contained in NASA HDBK-6003, Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods/Techniques.

4.2.4.4 Data Matrix Symbol Size

Symbol size is directly related to the amount of data encoded in the symbol and the fidelity of the marker. Symbol size is determined by establishing the number of rows and columns needed to contain the encoded part information (see Table 4-29) and multiplying that number by the data cell size to be produced by the marker. For instance, a symbol containing 20 characters of ASCII data can be stored in a symbol with 20 rows and columns. If the operator elects to use a dot peen marker that produces a data-cell size of 0.022inch (0.559mm), the overall symbol size is 0.044inch square (1.118mm), (20 x 0.022 = 0.044), (20× 0.559=1.118mm.)

TABLE 4.2-9 Symbol Size Calculation Chart

Data Matrix Parameters ECC 200							Information Capacity			Data Matrix cell sizes 0.003 , 0.008, 0.010, 0.20, .040 Data Matrix symbol size is returned below (Cell and symbol sizes are in inches)				
Rows	x	Columns	Data Regions	Data Bytes	Error Bytes	Percent ECC	Numeric Only (0-9)	Alphanumeric (0-9, A-Z, space) or (0-9, a-z, space)	8-bit ASCII (0-255)	0.003	0.008	0.010	0.020	0.040
10	X	10	1	3	5	62.5	6	3	1	0.03 x 0.03	0.08 x 0.08	0.10 x 0.10	0.20 x 0.20	0.40 x 0.40
12	X	12	1	5	7	58.3	10	6	3	0.04 x 0.04	0.10 x 0.10	0.12 x 0.12	0.24 x 0.24	0.48 x 0.48
14	X	14	1	8	10	55.6	16	10	6	0.04 x 0.04	0.11 x 0.11	0.14 x 0.14	0.28 x 0.28	0.56 x 0.56
16	X	16	1	12	12	50.0	24	16	10	0.05 x 0.05	0.13 x 0.13	0.16 x 0.16	0.32 x 0.32	0.64 x 0.64
18	X	18	1	18	14	43.8	36	25	16	0.05 x 0.05	0.14 x 0.14	0.18 x 0.18	0.36 x 0.36	0.72 x 0.72
20	X	20	1	22	18	45.0	44	31	20	0.06 x 0.06	0.16 x 0.16	0.20 x 0.20	0.40 x 0.40	0.80 x 0.80
22	X	22	1	30	20	40.0	60	43	28	0.07 x 0.07	0.18 x 0.18	0.22 x 0.22	0.44 x 0.44	0.88 x 0.88
24	X	24	1	36	24	40.0	72	52	34	0.07 x 0.07	0.19 x 0.19	0.24 x 0.24	0.48 x 0.48	0.96 x 0.96
26	X	26	1	44	28	38.9	88	64	42	0.08 x 0.08	0.21 x 0.21	0.26 x 0.26	0.52 x 0.52	1.04 x 1.04
32	X	32	4	62	36	36.7	124	91	60	0.10 x 0.10	0.26 x 0.26	0.32 x 0.32	0.64 x 0.64	1.28 x 1.28
36	X	36	4	86	42	32.8	172	127	84	0.11 x 0.11	0.29 x 0.29	0.36 x 0.36	0.72 x 0.72	1.44 x 1.44
40	X	40	4	114	48	29.6	228	169	112	0.12 x 0.12	0.32 x 0.32	0.40 x 0.40	0.80 x 0.80	1.60 x 1.60
44	X	44	4	144	56	28.0	288	214	142	0.13 x 0.13	0.35 x 0.35	0.44 x 0.44	0.88 x 0.88	1.76 x 1.76
48	X	48	4	174	68	28.1	348	259	172	0.14 x 0.14	0.38 x 0.38	0.48 x 0.48	0.96 x 0.96	1.92 x 1.92
52	X	52	4	204	84	29.2	408	304	202	0.16 x 0.16	0.42 x 0.42	0.52 x 0.52	1.04 x 1.04	2.08 x 2.08
64	X	64	16	280	112	28.6	560	418	277	0.19 x 0.19	0.51 x 0.51	0.64 x 0.64	1.28 x 1.28	2.56 x 2.56
72	X	72	16	368	144	28.1	736	550	365	0.22 x 0.22	0.58 x 0.58	0.72 x 0.72	1.44 x 1.44	2.88 x 2.88
80	X	80	16	456	192	29.6	912	682	453	0.24 x 0.24	0.64 x 0.64	0.80 x 0.80	1.60 x 1.60	3.20 x 3.20
88	X	88	16	576	224	28.0	1152	862	573	0.26 x 0.26	0.70 x 0.70	0.88 x 0.88	1.76 x 1.76	3.52 x 3.52
96	X	96	16	696	272	28.1	1392	1042	693	0.29 x 0.29	0.77 x 0.77	0.96 x 0.96	1.92 x 1.92	3.84 x 3.84
104	X	104	16	816	336	29.2	1632	1222	813	0.31 x 0.31	0.83 x 0.83	1.04 x 1.04	2.08 x 2.08	4.16 x 4.16
120	X	120	36	1050	408	28.0	2100	1573	1047	0.36 x 0.36	0.96 x 0.96	1.20 x 1.20	2.40 x 2.40	4.80 x 4.80
132	X	132	36	1304	496	27.6	2608	1954	1301	0.40 x 0.40	1.06 x 1.06	1.32 x 1.32	2.64 x 2.64	5.28 x 5.28
144	X	144	36	1558	620	28.5	3116	2335	1555	0.43 x 0.43	1.15 x 1.15	1.44 x 1.44	2.88 x 2.88	5.76 x 5.76
8	X	18	1	5	7	58.3	10	6	3	0.02 x 0.05	0.06 x 0.14	0.08 x 0.18	0.16 x 0.36	0.32 x 0.72
8	X	32	2	10	11	52.4	20	13	8	0.02 x 0.10	0.06 x 0.26	0.08 x 0.32	0.16 x 0.64	0.32 x 1.28
12	X	26	1	16	14	46.7	32	22	14	0.04 x 0.08	0.10 x 0.21	0.12 x 0.26	0.24 x 0.52	0.48 x 1.04
12	X	36	2	22	18	45.0	44	31	20	0.04 x 0.11	0.10 x 0.29	0.12 x 0.36	0.24 x 0.72	0.48 x 1.44
16	X	36	2	32	24	42.9	64	46	30	0.05 x 0.11	0.13 x 0.29	0.16 x 0.36	0.32 x 0.72	0.64 x 1.44
16	X	48	2	49	28	36.4	98	72	47	0.05 x 0.14	0.13 x 0.38	0.16 x 0.48	0.32 x 0.96	0.64 x 1.92

The "Information Capacity" value for alphanumeric mode can be larger when some numeric numbers are together and can be smaller when the upper and lower case alphabet are applied.

- Minimum recommended value is 1 cell size on all sides. Use zero if you do NOT want the quiet zone included in the calculations.

4.2.4.5 Data Matrix Cell Size by Environment

Decoding software examines each data cell to determine if it is filled or not (dark or light). If the grayscale average in the data cell is more than 50 percent, the software classifies the data cell as dark and assigns it a value of 1. If the grayscale average in the data cells is less then 50 percent, the cell is classified as light and assigned a value of 0.

Smaller data cells are more likely to incur damage to more than 51 percent of the data cell rendering the call unreadable. Symbols with large cell sizes are more likely to retain more than half of their structure when damaged and can be reconstructed by the decode software.

Consequently, cell sizes must be enlarged to overcome damage anticipated in harsh manufacturing, operational, and overhaul environments. Suggested data cell sizes by environment are illustrated in Figure 4.2-9.

No Minimum size for Protected Environments

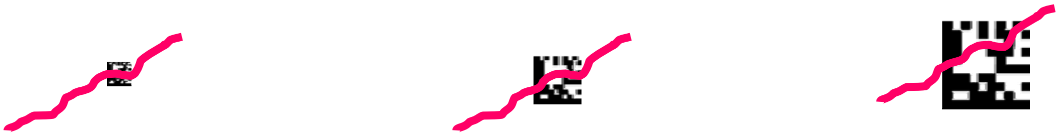
No cell size limit

Minimum cell size for Moderate Damage

0.010 inch

Minimum cell size for Harsh Environment

0.020 inch or larger



***Mark unreadable in Unprotected environment**

***Mark readable using error correction**

***Less or no error correction needed**

Note: Cell sizes must be adjusted upwards as surface roughness increases.

FIGURE 4.2-9. Minimum Cell Sizes for Expected Use Environments

4.2.4.6 Marking Locations

Data Matrix decoding software requires a minimum of one data cell width of clear space (quiet zone) around the symbol to be read successfully. However, due to variations in surface finish, this requirement has been extended to 10 percent of the longest symbol side on NASA programs. In addition to this requirement, manufacturers often impose additional marking location restrictions within their drawings and/or specifications. These documents consider the effect that the markings have on the product's form, fit, and function. They also address symbol positioning as it relates to marking device clearance and reading during manufacture and after assembly. Unless otherwise directed, Data Matrix symbols shall not be applied in the following locations:

- High traffic areas
- Highly polished curved surfaces (RMS 0 to 8)
- In direct air streams (e.g., leading edge of wings, helicopter rotors, exposed portions of turbine blades, etc.)
- Near high heat sources
- Sealing surfaces
- Wearing surfaces

In addition, operators must consider the effects of adjacent structures on the reader's illumination source. Fixed-station readers with movable light sources can generally be configured to successfully illuminate symbols placed in recesses or adjacent to protruding structures. These structures, however, can pose a challenge for hand-held readers with fixed-positioned light sources. Consequently, markings to be read in the field must be positioned for a sufficient amount of illumination to be projected to the symbol (see section 4.2.4.8).

4.2.5 Re-marking Requirements

This standard considers the material degradation caused by the application of a single human-readable and/or Data Matrix symbol applied using an intrusive marking method. Additional intrusive markings made to obliterate original markings and/or to add markings to correct errors or define changes may further reduce material properties beyond acceptability. Therefore, additional part identification markings shall not be permitted without approval.

4.2.6 Protective Coatings

Although metals often appear to be permanent, they are unstable in their operational environments and are susceptible to degradation by corrosion. This occurs when protective mechanisms have not been used or have been determined as no longer effective, leaving the metal vulnerable to hostile environments. Corrosion control is essential in the aerospace industry. Coatings are applied to marked surfaces to protect the marking and prevent corrosion. Intrusive markings applied to a surface that has been coated must be re-coated to prevent corrosion.

A protective coating shall be required when marks are subjected to wear, frequent handling, or environmental conditions that can damage the mark. The coating shall be clear and shall provide a protection level equal to or greater than the original protect finish. The coating shall not result in contamination later in the process and during ground, sub-orbital, and orbital operations. Matte finish coatings are preferable over gloss for readability. Typical coatings include, but are not limited to, the following.

4.2.6.1 Clear Anodize (MIL-A-8625E)

Anodizing is an electrolytic-oxidation process in which the metal surface, when anodic, is converted to a coating having desirable protective, decorative, or functional properties.

4.2.6.2 Lacquer (TT-L-50)

Lacquer is a coating based on thermoplastic film-forming material dissolved in organic solvent. The coating dries primarily by evaporation of the solvent. Typical lacquers include those based on lac, nitrocellulose, other cellulose derivatives, vinyl resins, acrylic resins, etc. Softer deposits are described as varnishes or gums.

4.2.6.3 Thin-Film Deposition

Thin-film deposition is a process involving the deposition of a clear metal film onto a substrate in a vacuum by metal evaporation techniques.

4.2.7 Mark Quality Verification

Data Matrix symbol markings shall be verified for quality in accordance with ISO/international electrotechnical commission (IEC) working draft (WD) 15415 as modified in Table 4.2-10.

Table 4.2-10 Mark Quality Verification Values

Grade	Action	*Symbol Contrast	Fixed Pattern Damage	Axial Non-Uniformity	Grid Non-Uniformity	Modulation	Unused Error Correction
4 (A)	Best	≥0.50	0%	≤0.06	≤0.38	≥0.50	≥0.62
3 (B)	Minimum at point of marking	≥0.40	≤9%	≤0.08	≤0.50	≥0.40	≥0.50
2 (C)	Minimum in use	≥0.30	≤13%	≤0.10	≤0.63	≥0.30	≥0.37
1 (D)	Fail - remark	≥0.20	≤17%	≤0.12	≤0.75	≥0.20	≥0.25
0 (F)	Worst	<0.20	>17%	>0.12	>0.75	<0.20	<0.25

*ISO Standard Values reduced. Information based on test results from external sources in partnership with NASA.

The overall grade shall be represented by the lowest of the values above. On NASA programs, the minimum acceptable symbol grade at point of marking shall be “B.” Since some marks degrade slightly while in service, a grade of “C” is acceptable in use. Marks failing to meet the required grade of “C” or better during use or following repair, refurbishment, or overhaul, shall be dispositioned per written requirements.

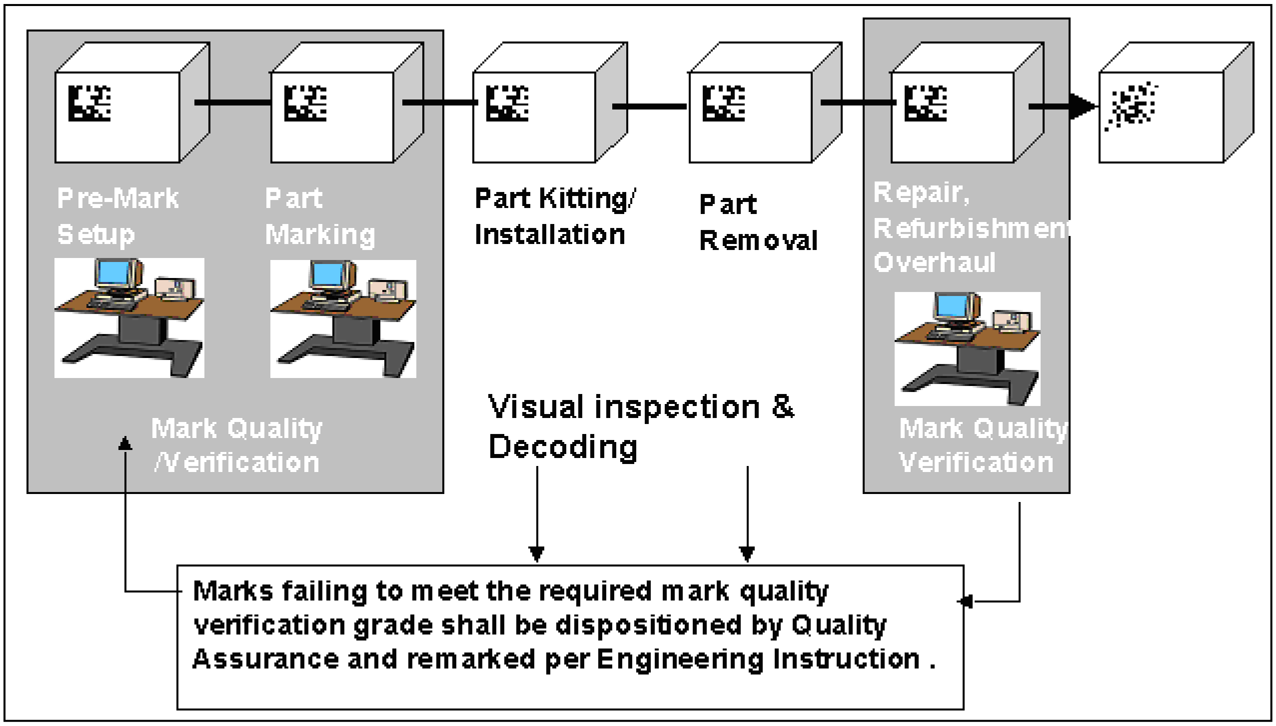


FIGURE 4.2-10 Mark Quality Verification Points

Mark quality verification equipment shall be configured to read the full range of symbol sizes reflected in Table 4.2-1, and fitted with the lighting (direct, low-angle and/or diffused illumination) required to eliminate glare or shadowing that may alter the appearance of the captured symbol image.

In-service reading should result in good reads. Bad-reads or no-reads resulting from bad-marks shall be reported for disposition. See section 3.2 for definitions.

4.2.8 Reading Requirements

Data Matrix readers vary in their ability to read the Data Matrix on highly reflective or rough surfaces. The different reader types also operate with maximum effectiveness at varying distances from the surface containing the mark. Near contact of touch readers may be hindered by protruding structures, or may be unable to focus on the marks. Other readers that operate from a distance to the surface may have their illuminators shadowed when viewing marks placed in recessed areas or surrounded by protrusions. Therefore, the proper placement of the mark is a tradeoff between 1.) the areas on the part that may be marked and 2.) the areas on which the Data Matrix reader is effective. Thus, the properties and limitations of the Data Matrix reader must always be considered. In general, this leads to preferring a less-reflective and smoother surface that is not deeply recessed or near protrusions.

5. GUIDANCE

5.1 Reference Documents

The documents cited in this section are listed for reference only. The specified technical requirements listed in the body of this document must be met whether or not the source document is listed in this section.

5.1.1 Government Documents

5.1.1.1 Specifications, Standards and Handbooks

DEPARTMENT OF DEFENSE

MIL-A-8625 – Anodic Coatings For Aluminum And Aluminum Alloys

MIL-A-21380 - Abrasive Materials, For Blasting

MIL-C-38736 - Cleaning Compound, Solvent Mixtures (Metric)

MIL G-5634 - Grain, Abrasive, Soft, For Carbon Removal

MIL-G-9954 - Glass Beads, For Cleaning and Peening

MIL-H-6875 - Heat Treatment of Steel, Process For

MIL-I-25135E - Inspection Materials, Penetrants

MIL-P-85891 - Plastic Media, For Removal of Organic Coatings

MIL-STD-10A - Surface Roughness Waviness and Lay

MIL-STD-869 - Flame Spraying

MIL-STD-871 - Electro-Chemical Stripping of Inorganic Finishes

MIL-STD-13231 – Marking of Electronic Items

MIL-STD-130L – Identification Marking of U.S. Military Property

MIL-STD-1504 - Abrasive Blasting

MIL-STD-6866 - Inspection, Liquid Penetrant

Copies of these documents are available online at http://assist.daps.dla.mil/quicksearch/ or www.dsp.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

FEDERAL STANDARDS

FED-STD-595 – Colors Used In Government Procurement (Fan Deck)

SAE-AMS-2806 - Identification, Bars, Wire, Mechanical Tubing And Extrusions, Carbon And Alloy Steels And Corrosion and Heat Resistant Steels and Alloys

SAE-AMS-2807 - Identification, Carbon And Low-Alloy Steels, Corrosion And Heat Resistant Steels And Alloys Sheet, Strip, Plate, And Aircraft Tubing

SAE-AMS-STD-184 - Identification Marking of Aluminum, Magnesium, And Titanium

SAE-AMS-STD-185 - Identification Marking of Copper And Copper Base Alloy Mill Products

Copies of the SAE documents are available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or http://www.sae.org/servlets/index

5.1.1.2 Other Government Documents, Drawings, and Publications

Title 14 of the Code of Federal Regulations

5.1.2 Non-Government Documents

AIAG B4, Parts Identification and Tracking Application Standards – Pending

AIM International Symbology Specification – Data Matrix

AIM USA Uniform Symbology Specification for Data Matrix

American National Standard X3.182 Bar Code Print Quality Guidelines

AMS-S-13165 - Shot Peening of Metal Parts

ANSI T1.220 Information Interchange - Coded Representation of the North American Telecommunications Industry Manufacturers, Suppliers, and Related Service Companies

ASME B46.1-02, Surface Texture (Surface Roughness, Waviness, and Lay)

ASM Handbook, Surface Engineering, Volume 5
ASTM B-117-03, Standard Practice for Operating Salt Spray (Fog) Apparatus

ASTM D-522-93, Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings

ASTM D-673-93, Standard Test Method for Mar Resistance of Plastics

ASTM D-870-02, Standard Practice for Testing Water Resistance of Coatings Using Water Immersion

ASTM D-1003-02, Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics Transparency

ASTM D-1308 (with addition of sulfuric acid testing), Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes

ASTM D-2247-02, Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity

ASTM D-2485-91(2000), Standard Test Methods for Evaluating Coatings For High Temperature Service

ASTM D-2794-93 (2004), Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

ASTM D-3359-02, Standard Test Methods for Measuring Adhesion by Tape Test

ASTM D-3363-00, Standard Test Method for Film Hardness by Pencil Test

ASTM D-3794-94, Standard Guide for Testing Coil Coatings

ASTM D-4060-01, Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

ASTM E-96-95, Standard Test Methods for E96-95 Water Vapor Transmission of Materials

ASTM E-96-01el, Standard Test Methods for E96-95 Water Vapor Transmission of Materials

ASTM G-23-96, Standard Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials

ASTM G-26-95, Standard Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials

ASTM G-53-96, Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials

ASTM G-120, Standard Practice for determination of Soluble Residual Contamination in Materials and Components by Soxhlet Extraction

ASTM G-131-96, Standard Practice for Cleaning of Materials and Components by Ultrasonic Techniques

ASTM G-144-1996, Standard Test Method for Determination of Residual Contamination of Materials and Components by Total Carbon Analysis Using a High Temperature Combustion Analyzer

ASTM G-154, Standard Practice for Fluorescent for UV Exposure of Nonmetallic Materials

ASTM G-155, Standard Practice for Operating Xenon-Arc Light Apparatus for Exposure of Non-metallic Materials

ATA SPEC-2000, E-Business Specifications for Materials Management, Chapter 9, Bar Coding

EIA-624, Product Package Bar Code Label Standard for Non-Retail Applications

EIA-706, Component Marking Standard (Data Matrix)

EIA-802, Product Marking Standard

EIA SP-3497, Component Product Marking Standard (Data Matrix)

ISO/IEC 15415, 2-D Symbol Print Quality – Pending

ISO/IEC 16022, Information Technology International Symbology Specification Data Matrix

SEMI T2-98, Specification for Marking of Wafers with 2-D Matrix Code Symbol

SEMI T7-0997, Specification for the Back Surface of Double-Sided Polished Wafers with a 2-D Matrix Code Symbol

SEMI T8-0698, Specification for Marking of Glass Flat Panel Display Substrates with A 2-D Matrix Code Symbol

SEMI T9-2000, Specification for Marking Metal Lead-Frame Strips With 2-D Matrix Code Symbols

SEMI Draft Document #2999, Specification for the Assessment of 2D Data Matrix Direct Mark Quality

TT-C-490, Chemical Conversion Coatings and Ptetreatments for Ferrous Surfaces (Base for Organic Coatings)

TT-L-50 - Lacquer, Nitrocellulose, Acrylic and Acrylic Butyrate, Aerosal (In Pressurized Dispensers)

Uniform Code Council (UCC) Standards

Uniform Symbology Specification for Data Matrix available from AIM

UPS S28-1, Identification/Codification Standards (Data Matrix and PDF417)

5.2 Key Word Listing

Configuration management
Data Matrix
Direct part marking
License tag number
Machine-readable code
Machine-readable symbol
Part cleaning
Part finish
Part identification
Part marking
Part tracking
Protective coating

5.3 Background

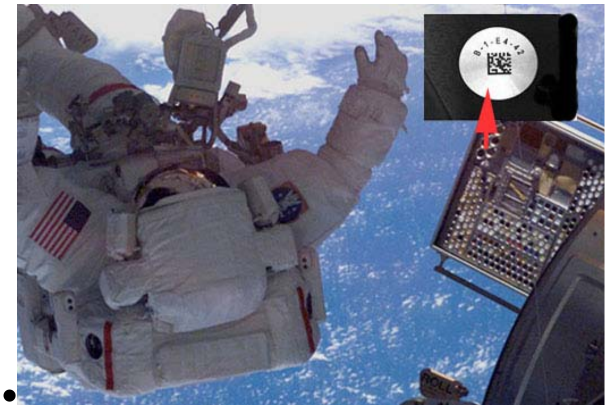
Recognizing that manual data collection and keyed data entry were inefficient and error-prone, National Aeronautics and Space Administration (NASA) adopted bar code technology in the mid-1980s to upgrade its operations. It soon became apparent that collecting the identity of the part from a symbol marked directly on it would be optimal. Bar codes were determined not to be suitable for direct-part marking (DPM). NASA established a team to work with industry to develop and test machine-readable two-dimensional (2-D) symbols designed to be applied to non-paper substrates. This 5-year effort resulted in the selection of the Data Matrix symbol for use in NASA applications, and provided proof that 2-D symbols are reliable and can be applied to most aerospace materials without impacting performance. NASA findings spurred additional testing by the Department of Defense (DoD) and private industry resulting in selection of the Data Matrix symbol for parts marking by the Automated Identification Manufacturers (AIM) and the American National Standards Institute (ANSI). Additional part marking standards quickly followed as the automotive, electronics, pharmaceutical, and aircraft industries adopted the symbol.

These industries, including NASA, have relied heavily on the use of mold, cast, or forge; engraving, electrical arc pencil, electrical-chemical marking, embossing; hot stamp, rubber ink stamp, stencil and silk screen, and vibration-etch for part identification marking. These marking methods, originally designed to apply human-readable markings, do not provide the fidelity needed to successfully mark high-density machine-readable symbols. Their manual operations also added to the number of data transposition errors associated with paper-based manufacturing systems.

Understanding these weaknesses, the parts identification industry began to refine existing marking methods so they could be utilized to apply 2-D symbols. The manual metal stamp, vibro-etch, and embossing technique methods were replaced by dot peen machines. Automated micro-profilers were designed to replace the manual cutting wheel used to produce paint stencils. Photo stencils and thermal printing materials were developed to replace the direct -impact electro-chemical marking stencils. Ink-jet and adhesive-dispensing machines were built to replace rubber stamps. Laser marking systems were designed to replace the electric-arc etch and hot-stamp processes. These methods and other new marking processes have been incorporated into this standard.

APPENDIX A:

MISSE PROGRAM INFORMATION



MISSE was launched into LEO on August 9, 2001 at 5:38 PM on the Space Shuttle Discovery (Mission STS-105). The experiment was attached to the International Space Station by astronaut Patrick G. Forrester as part of an extravehicular Activity (EVA), commonly called a spacewalk.

Included in the experiment trays are number disks with typical spacecraft materials marked with Data Matrix symbols, using a wide range of marking processes. The trays are oriented to expose the disks to LEO environments. These include extreme levels of ultraviolet radiation, atomic oxygen, hard vacuum, and contamination, which have a strong degrading effect on some types of materials. Photographs of the markings taken after 1 year of exposure verify that the new processes are working. Data obtained after retrieval is to be incorporated into Table 4.2-7 of this standard.

Qualifying materials for long-term use in space are made especially challenging because this unique environment is so difficult to simulate in a laboratory. With MISSE, no laboratory is needed. On-orbit testing is accomplished by flying the materials outside the International Space Station for a period of one to three years. The marked Data Matrix disks are installed in two Passive Experiment Containers (PECs). The two containers are scheduled to be retrieved during the second Space Shuttle mission following return to flight, and are to be analyzed to determine the preferred marking sizes and processes used to apply part identification markings on future reusable spacecraft. Placeholders for this data have been incorporated into this revision of the standard.

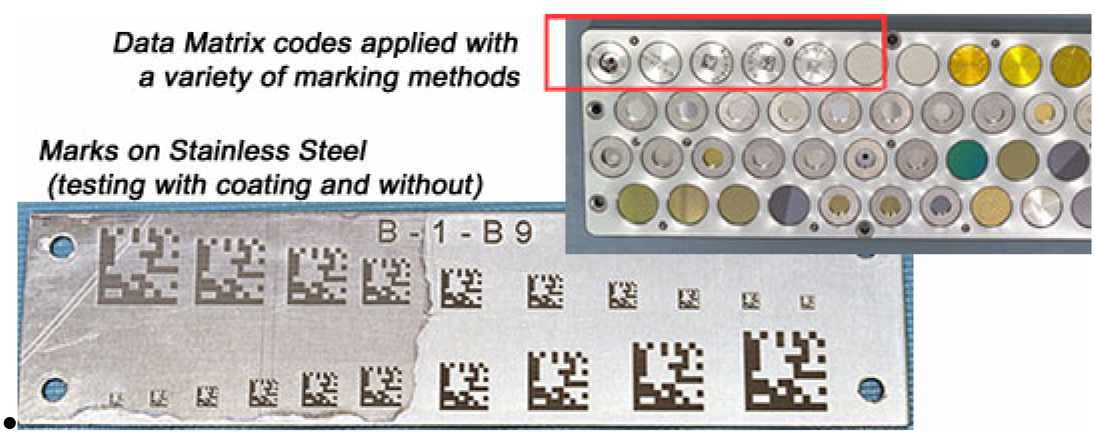


TABLE A-1 MISSE Marking Sample Data

Specimen Number	Base Material	Marking Method	Marking Material	Encoded Info.	Planned Orbit Duration	Color of Mark	Initial Grade	Post Flight Grade	Marking Equipment
B-1-E3-27	Glass	LIVD	Brass	Line Pattern	1 yr.	Dark Brown	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E3-28	Glass	LIVD	Tin	Line Pattern	1 yr.	Black	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E3-29	Glass	Laser Bonding	Cerdec RD-6005	Line Pattern	1 yr.	Gray-Black	Excellent Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E3-30	Glass	VAVD	Copper	Line Pattern	1 yr.	Dark Gray	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E3-31	Glass	LIVD	Tin	B1E331	1 yr.	Black	A		Rofin-Sinar Nd:YAG Laser
B-1-E10-03	Glass	LIVD	Brass	Line Pattern	1 yr.	Dark Brown	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E10-04	Glass	LIVD	Tin	Line Pattern	1 yr.	Black	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E10-05	Glass	Laser Bonding	Cerdec RD-6005	Line Pattern	1 yr.	Gray-Black	Excellent Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E10-06	Glass	VAVD	Copper	Line Pattern	1 yr.	Dark Gray	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E10-07	Glass	LIVD	Brass	B1E107	1 yr.	Dark Brown	A		Rofin-Sinar Nd:YAG Laser

TABLE A-1 MISSE Marking Sample Data (continued)

Specimen Number	Base Material	Marking Method	Marking Material	Encode d Info.	Planned Orbit Duration	Color of Mark	Initial Grade	Post Flight Grad e	Marking Equipment
B-1-E4-42	Aluminum	Laser Bonding	Cerdec RD-6000	B1E442	1 yr.	Black	A		Rofin-Sinar Nd:YAG Laser
B-1-E4-43	Glass	Laser Bonding	Cercec RD-6005	B1E443	1 yr.	Black	A		Rofin-Sinar Nd:YAG Laser
B-1-E4-44	Aluminum	VAVD	Copper	B1E444	1 yr.	Whit e	A		Rofin-Sinar Nd:YAG Laser
B-1-E4-45	Aluminum	GALE	Argon Gas	CiMatx	1 yr.	Dark Gray	A		LMT Diode-Pumped Laser
B-1-E4-46	Aluminum	Chemical Etching	SCE-4	B1E446	1 yr.	Gray	A		Electo-Chem Etch Machine
B-2-E16-42	Aluminum	Dot Peen	N/A	2E1642	3 yrs.	Whit e	A		Telesis TMP 6000 Pinstamp
B-2-E16-43	Aluminum	Laser Etching	N/A	2E1643	3 yrs.	Dark Gray	A		Rofin-Sinar Nd:YAG Laser
B-2-E16-44	Aluminum	LISI	Metallic Powders	2E1644	3 yrs.	Dark Gray	A		Rofin-Sinar Nd:YAG Laser
B-2-E16-45	Aluminum	Laser Shot Peening	N/A	2E1645	3 yrs.	Whit e	B		Neodymium-Doped glass laser
B-2-E16-46	7980 Glass (Corning)	LIVD	Tin	2E1646	3 yrs.	Black	A		Rofin-Sinar Nd:YAG Laser
B-1-B9	Aluminum Plate	Laser Etching	N/A	123456	3 yrs.	Gray	A		Rofin-Sinar Nd:YAG Laser

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APPENDIX B:

Examples of Sensor-Based Readers

Magneto-optic Reader: Contract reader. The imager shown to the right produces images of magnetic fields emitted from the magnetic material used in the marking medium that forms the desired Data Matrix pattern.

Ultrasound Reader: Contact reader. The imager detects differences in acoustic impedance (density) or variations in the reflected acoustic pattern (surface texture), or both.

Capacitance Reader: Contact reader. The imager detects resistance to current flow through a material.

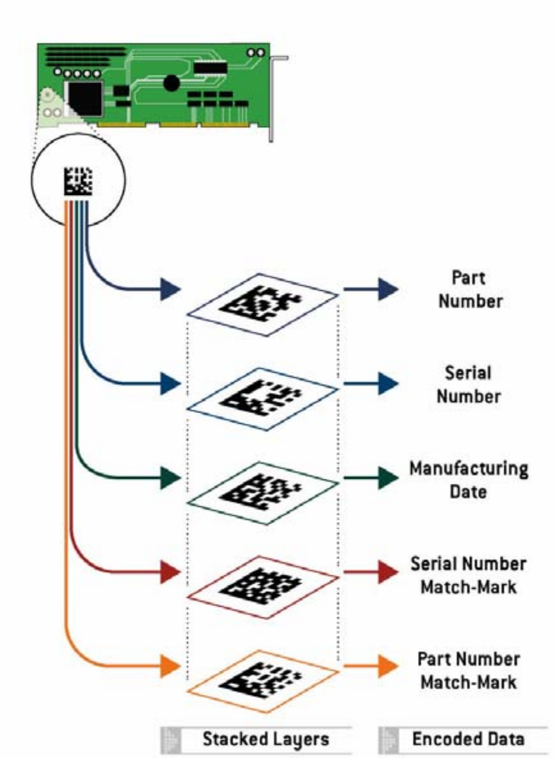
Micro-Impulse Radar Reader: Non-contact reader. The imager detects differences in radio-signal return times or strength within a predetermined time interval.

Thermal or Infrared Reader: Non-contact reader. Marking materials must provide an emissivity or reflectance level that differs from that of the host product.

X-Ray Reader: Non-contact reader. The imager detects areas of greater density by passing a beam through the product to expose an underlying x-ray sensitive film.

Stacked Data Matrix Codes: Mixed contact and non-contact.

Sensor readers provide the capability to distinguish markings that are hidden for aesthetic or security reasons. Each sensor type detects materials with specific characteristics, and in some cases, can locate these materials at specific depths (making them suited for the detection of stacked symbols). This eventually leads to the placement of large amounts of data in limited marking areas. The stacked symbol in the adjacent figure illustrates that.



Identification data encoded in matrix symbols would be marked on layers, and the layers would be stacked

Each layer would be marked with a substance that is sensed by a different method.

Layers would represent identifying designations, such as part number or serial number, but recognizable only to a specific scanner.

Applications include those where security is needed or for anti-counterfeiting of identification marks precluded by complexity.

APPENDIX C:

x-Ray Fluorescence Detection Systems

C.1 Identification

Today, part identification technologies that are used on aircraft, aerospace, or military parts are primarily the human-readable designations marked where space is available on the substrate that is topographically suitable for marking. Those parts that lack the substrate space or topographical suitability usually do not have their identity marked directly on them. Their identity is marked on the bags in which they are packaged for protection or the containers that are used for their shipping. Marking bags and containers with labels provides the opportunity to use bar codes and collect part identity accurately one time. Once these parts are removed from their packaging, traceability is lost because their identity is separate from them and automatic data collection is not possible. At this point, the nonidentity of these parts causes them to become usage items, having to be scrapped the first time they are serviced, since they have no verifiable link to a database for tracking.

For example, under FAA regulations, all aircraft parts manufactured without FAA approval are unapproved parts. This generic classification includes counterfeit parts, stolen parts, production overruns sold without authorization, parts exceeding their time limits, approved parts improperly returned to service, fraudulently marked parts, or parts that have no traceability. These unapproved parts are difficult, if not impossible, to identify and currently represent a significant percentage of existing DoD inventories. NASA experiences this problem to a much lesser degree, but with the FAA, DoD and NASA having so many common suppliers, NASA is susceptible to part identification and verification problems.

Direct part marking very small Data Matrix symbols remedies the situation for many of these parts and provides a link to their pedigree throughout their life cycle. Where nonidentity currently exists, resulting in low-quality or unapproved parts, the transition to direct part marking of Data Matrix symbols eliminates human error and provides a basis for part verification.

There are many parts that still cannot be marked with Data Matrix symbols due to stress considerations, size, or other factors. Small damping seals, thin diaphragms and some polymers are examples of delicate or difficult parts to mark. For these parts, a chemical taggant has been devised that can serve as a Data Matrix or bar code, representing a portion of the part identity linked to the pedigree database. The chemical taggant is sprayed on, built, or contained in a coating, and is detected by x-ray fluorescence. An x-ray fluorescence scanner is used to read the taggant. The hand-held scanner (shown below) detector (shown below the scanner) is placed in contact with the part where the taggant is present. The device can evaluate chemical compositions in a matter of seconds. The XRF technology, therefore, provides a reliable solution to the identification of parts that are otherwise difficult to mark with Data Matrix symbols. This solution has the potential of preventing reusable parts from being discarded due to absence of adequate identification.

FIGURE C.1-1 Hand-held Scanner and Detector

x-ray fluorescence works by devising a chemical taggant of known composition: Taggants are mixtures of known chemicals at known concentrations that are integrated onto an object for identification or authentication.

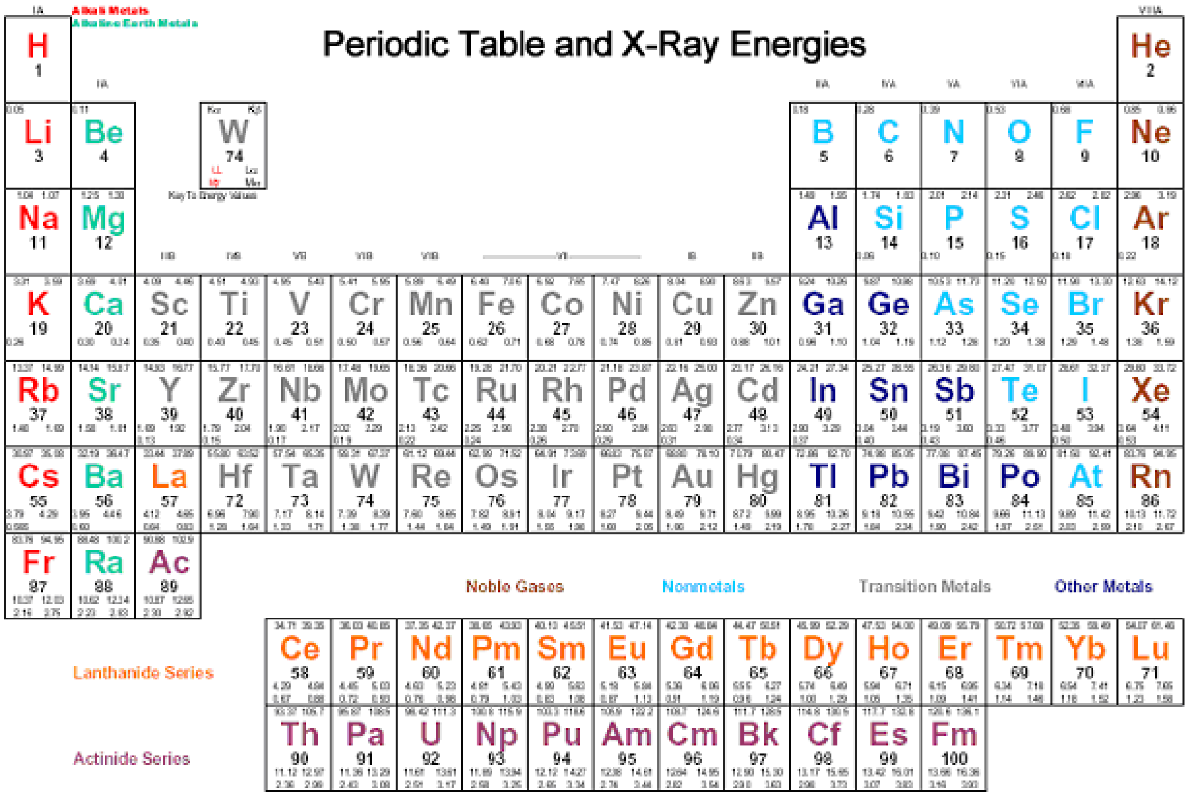


FIGURE C.1-2 Periodic Table and X-ray Energies

When the x-ray fluorescence scanner is activated, some of the x-rays from the instrument strike and eject electrons from the inner shell of the atoms in the target. Next, an electron from an outer shell fills the space in the inner shell. An x-ray photon is released and hits the detector. This photon’s energy is unique to the element it came from, e.g., K-shell Aluminum at 1.87keV).

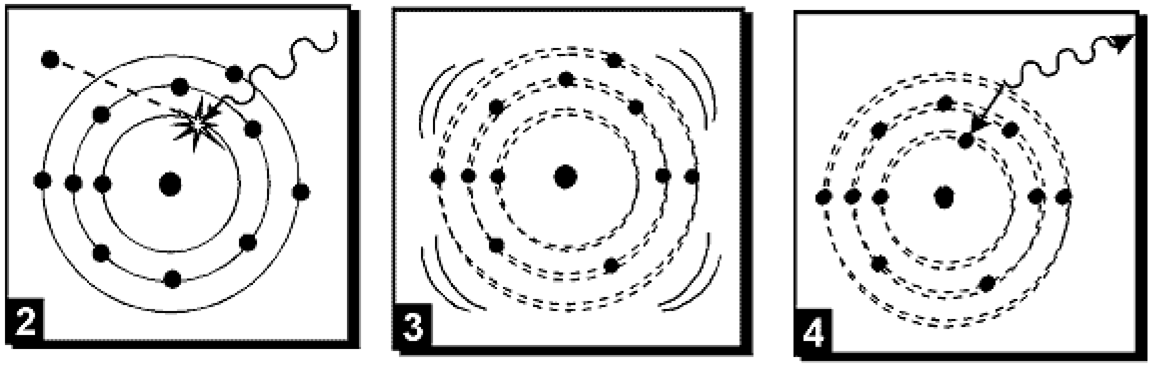


FIGURE C.1-3A X-ray Energies

Each element has its own signature energy for K and L electron shells. The taggant is decoded by software contained in the detection device and communicated to a database in the same manner as a Data Matrix symbol or bar code. Each taggant element represents a different letter or number in the ASCII Table, the arrangement of which relates to the identity of a part.

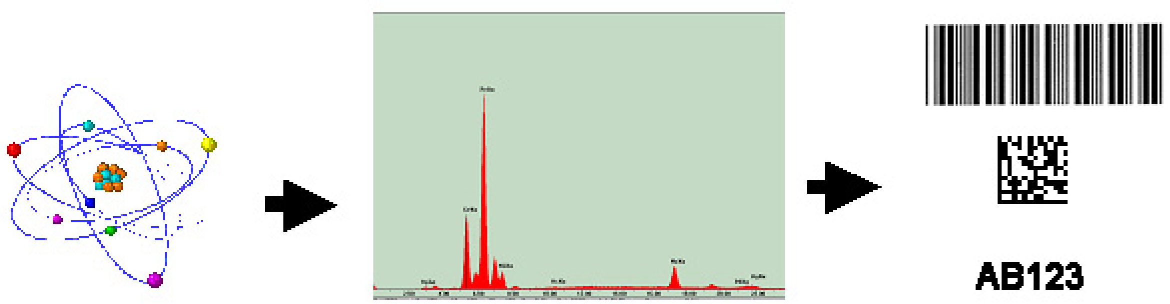


FIGURE C.1-3B X-ray Energies

C.2 Authentication

Authentication is the other useful application of XRF tagging. Authentication is defined as confirming that a part is genuine.

Today, there is no way to authenticate a part by scanning a Data Matrix symbol or bar code, both being fairly generic in design and application, and easily counterfeited. Bar codes and other labels that are marked on packaging or containers can be replaced by other stick-on labels and can easily incorrectly identify unapproved parts. Symbols, such as Data Matrix, that are marked on parts can also be duplicated on unapproved parts until database safeguards prohibit their use. Currently, both labels and direct marks can only be used for routine part identification.

XRF elemental tagging can be used in combination with the other methods of part identification to form an authentication system for part identity. Working in conjunction with labels and direct marks, the intrinsic indestructible nature of XRF taggants serve as "secret bar codes" inside the part that repeat selected identity information contained in the other marks.

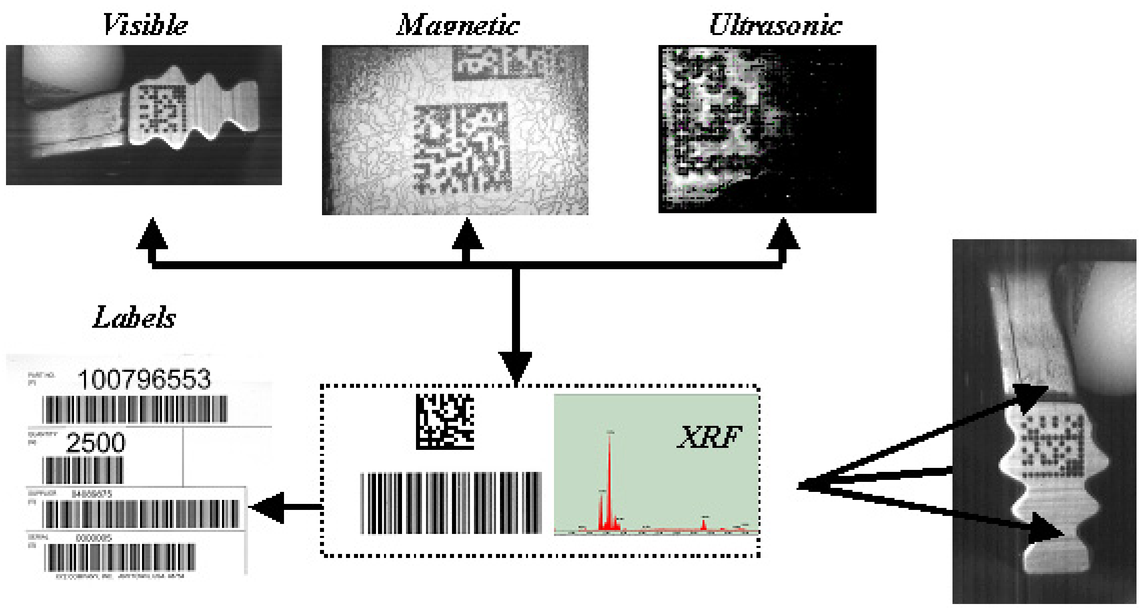


FIGURE C.2-1 Authentication

This method is especially useful in commercial anti-counterfeiting efforts. It is also extremely reliable factor in liability cases where the "secret bar code" is applied at the point of manufacture. When liability cases occur that possibly involve counterfeit parts, authentication technologies such as XRF "secret bar codes" firmly establish whether or not the part that failed was made by the manufacturer. NASA benefits from these part-authentication methods for acceptance, use, and overhaul.